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THE ROLE OF CENTERS FOR SCIENCE EDUCATION IN THE PRODUCTION, DEMONSTRATION, AND DISSEMINATION OF RESEARCH.

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PROCEEDINGS FROM A CONFERENCE HELD AT COLUMBUS, OHIO, FOR THE IMPROVEMENT OF RESEARCH IN SCIENCE EDUCATION ARE REPORTED. PAPERS PRESENTED AT THE CONFERENCE ANALYZED STRENGTHS AND WEAKNESSES OF RECENT RESEARCH IN SCIENCE EDUCATION, IDENTIFIED RESOURCES, MODELS, AND THEORY FOR IMPROVING RESEARCH IN SCIENCE EDUCATION, IDENTIFIED ISSUES AND PROBLEMS IN SCIENCE EDUCATION, REPORTED ON THE ORGANIZATION AND FUNCTIONS OF SCIENCE EDUCATION CENTERS, PROPOSED STRATEGIES FOR CHANGING EDUCATIONAL PRACTICE, AND SUGGESTED GUIDELINES FOR ORGANIZING THE RESEARCH ENTERPRISE IN SCIENCE EDUCATION TO FACILITATE RESEARCH ACTIVITIES AND INCREASE THE IMPACT OF RESEARCH FINDINGS ON CLASSROOM PRACTICE. A SUMMARY OF THE CONFERENCE PROCEEDINGS AND RECOMMENDATIONS OF THE CONFERENCE PARTICIPANTS IDENTIFY BASIC PROBLEMS IN SCIENCE EDUCATION RESEARCH AND SUGGEST ACTION FOR ALLEVIATING AND RESOLVING THESE DIFFICULTIES. THE SUGGESTIONS INCLUDE DEVELOPING A COORDINATING CENTER FOR SCIENCE EDUCATION WITH MULTIPLE FUNCTIONS TO ASSIST RESEARCHERS AND PRACTITIONERS CONCERNED WITH THE TEACHING AND LEARNING OF SCIENCE, PROVIDING INCREASED RESEARCH TIME FOR RESEARCHERS, DEVELOPING COOPERATIVE AND RELATED INVESTIGATIONS, AND IMPROVING COMMUNICATION AMONG RESEARCHERS AND BETWEEN RESEARCHERS AND PRACTITIONERS. (AG)

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By
John S. Richardson and Robert W. Howe

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Contract No. OE 5-10-335

By

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U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
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SECTION I

INTRODUCTION

Much evidence in the field of professional education points toward a steady and persistent growth. The need for improvement in professional education has been evident for many years and in response to this need many efforts have been made by individuals, committees and by various professional societies in the field. The various efforts have produced at least hopeful results, many of them being of considerable significance. A disturbing fact is that many efforts have been predicted on divergent goals revealing conflicting values. A paramount need lies in the production of research results which will demonstrate the more precise nature of the professional task, with more effective means for meeting it, and with results demonstrated to be more in keeping with our goals and the values in which they are nourished.

In relatively recent years the attention of the federal government became directed to the field of science; more recently the field of professional education has been given increased attention. The level of support has been such that those most concerned with both the academic and the professional aspects of science education have found it possible to develop plans methodically with an optimistic view toward the possibility of their realization.

The evident need in our society for a greater depth and breadth in science for our intelligent understanding, interpretation and action, and for the advance of our technology to improve man's lot and his control over his surroundings has spurred us on to thought and action. The evident growth of science and of its application have caused those persons in the field of science education to wish that the level of certainty of the content of professional education might be made as secure as the certainty of the academic component of science education.

Our knowledge of professional education is partial -- in both its theoretical and applied aspects. For example, more definite knowledge is needed in learning theory and concerning the desirable and effective behavior of the science teacher in the teaching-learning situation. Even with all our confidence in the appropriate role of content in the education of the individual, we seem to be working principally on the basis of hope and faith that the employment of the traditional systems of knowledge in the various fields of science are adequate to the most adequate development and exploitation of the intellect. But such hopes may necessarily wait until professional education has developed more adequate systems of evaluation of the learning of the individual student. Relatively little is known about the development of creativity and about its measurement. The professional world stands in need of the identification of the factors within and the structure of the situation in which the creative intellect is stimulated and permitted to rise to its highest level. Still inadequately explored is a substantiated theory of learning. The development of this professional knowledge may well open the way to an adequate system of evaluation of changes in behavior, and the fostering of creativity.

The eventual release of such insights with demonstrated validity is an essential condition to the usefulness of general professional knowledge in the development of science education. In turn science education has an obligation of its own to make its contribution to the general professional field. It should not depend upon the general field of professional education without in turn producing useful results coming from its own experience--both from experiment and research and from common experience--adding to the general understanding of the professional field. Only from the particular results in fields such as science education can a more valid general body of professional education be created. In fact, many investigations of learning theory have turned to science education not only because of its current value but also because of some aspects of its objective nature. Through this relative objectivity the field leads with some ease to perhaps more demonstrable generalizations than can easily be derived in those fields having a less objective content. However, this seeming advantage may also be a danger. The relative objectivity of the conventional concept of scientific information is often in the form of isolated bits of knowledge. The desired change in students behavior tends to be the memorization of such bits rather than such functional achievement as the ability to generalize using scientific information.

BACKGROUND FACTORS

During the nineteen thirties a general foment in education was initiated, largely the result of the outstanding leadership of John Dewey and those educators who joined him in an effort to move ahead in a field of great social significance but with relatively little identified content. Through these leaders and their supporters a considerable effort was made to improve the curriculum in our schools in both breadth and depth. Underlying these efforts were concepts, and terms to represent them, not unlike many that have characterized more recently supported efforts.

Much concern was expressed and studied as to the appropriate objectives of education. The concept of learning by doing was characterized by discovery and inquiry. The social implications of the various phases of education were held up to study; the field of science as an aspect of the school curriculum was one such to draw and receive a great deal of attention.

One of the effects of this foment was an extension of science into the elementary school, building upon as it did some of the earlier efforts that were characterized largely as nature study. A second development in this period of time was a further effort to produce a useful program in junior high school science. In a third dimension there was concern for a laboratory approach to science both in the junior high school program and through an extension of experimental work in secondary school biological science. A fourth development presaging certain of the current efforts, and the terms that are currently invoked, was the development of an experimental physical science course in the senior high school in several school systems.

However, several factors contributed to a cessation of the effort. In spite of the fact that considerable progress was made and much was done in the building of attitudes toward the improvement of science education, various factors tended to diminish the effectiveness of the efforts and even to bring them, for the time being, to a standstill.

1. The depression of the national economy in the nineteen thirties seriously restricted the financial support, with a reduction of the effectiveness of those efforts that had been begun.
2. The opening of World War II at the end of the thirties turned the attention of virtually everyone including the educators to the military aspects of national welfare, to the neglect of the underlying educational aspects of our welfare.
3. In part because of the economic situation the country suffered a lack of effort in the academic and professional preparation of teachers, particularly in the high school sciences.
4. In the period under consideration there were few research foundations to support the research that was needed.
5. The accumulation of such factors resulted in a paucity of adequate research procedures and products, not only in the natural sciences but in the social sciences as well.

SOME EDUCATIONAL EFFECTS OF WORLD WAR II

Growing out of the educational experience of World War II were several interrelated outcomes that perhaps could result only from a political and social upheaval. Among these was a development not only of new knowledge in the field of science but also new knowledge of social nature. It was demonstrated as never before that the need for adequate education is a critical element in the life of a nation. The evidence was imperative that the cooperation and interacting efforts of persons of a variety of competencies--educators, scientists, and engineers--are a critical facet of the growth of a culture. This idea had been developed and had grown in the culture of the humanities in earlier centuries. However, the development of the separate disciplines which had grown in their own specializations tended to erect separating walls.

Within this matrix, the field of science education could contribute only a modest amount of substantial research. Limited not only in its quantity, it has also the further shortcoming of being relatively unstructured and, what is worse, little external relatedness. Such was the setting for a society dedicated to the proposition that only through education can its form of life and government be protected, extended, and made more functional. The great challenge then became that of establishing adequate communication of ideas between those whose disciplines had emerged independently with their own formal structures (and thus a source of their own strength) and those whose discipline has social responsibility and social context. The future obviously lay and continues to lie in the further interaction of the fields of professional education, science, and engineering. The extension of research in science education is critical in a society for which the lifeline is the extension of education among its people, and particularly so to the quality of its living both spiritually and physically as it depends upon man's insight into the nature of the universe.

The present climate of international competition and aggression demands measures both constructive and imaginative, progress being at the greatest speed consistent with the adequacy of the measures. We must bend every effort to bring the full contributions of research, in both the sciences and the social fields, to bear on the values that underlie man's activities and enlarge his insight upon the breadth of his understanding and potential intellectual power.

WORLD WAR II AND THE SCIENCE EDUCATION PROGRAM

The effects of the war felt fully in the field of science education included a greater emphasis on science and technical education in high school and college programs. Accompanying this were increased requirements for grades and increasing difficulty in admission to the institutions of higher education. The task was greatly multiplied by the increasing enrollment of students in college; by those who had been delayed in their education because of the war and multiplied by those who might not otherwise have gone to college except for the obvious need for advanced education in all fields, particularly in the sciences, mathematics and engineering. The continuing international threat and unrest served to make that task even more complex.

Reexamination of educational programs revealed a considerable lack of confidence in the science programs in the schools and colleges. In retrospect this lack of confidence seems to have been in part justified and to some extent without foundation. Evaluations based on examinations revealed some weaknesses that very formally educated persons of relatively high ability could and did decry; however, the products of our educational system rose to the challenge. The present educational strength being challenged is whether our schools adequately prepared these same students with value systems and clear thought.

One major result of the national and international situation was that the National Science Foundation was created by the Congress. Through this foundation, attention was given initially and primarily to scientific research. Soon after, however, institute programs were developed to improve the academic preparation of both high school and college science teachers. Conferences of groups of scientists and of groups of science teachers were sponsored in an effort to determine new directions which should be undertaken in future program development. These programs include the summer institutes for science and mathematics teachers, the academic year institutes, in-service institutes, conferences as well as a broad spectrum of fellowships available to both high school science teachers and college science teachers.

The so-called curriculum studies of acronym identification, PSSC, CHEMS, CBA, BSCS, ESCP being the most common examples, were developed as hoped-for means of improving the school science program. Another effort of note was the creation of the Radiation Biology Institutes by the Atomic

Energy Commission. The development of these programs was approached in good faith by a variety of persons; many of them had no particular desire to look to the results of research in science education for curriculum development. But even if they had, little of definitive nature would have been found in that field.

Those responsible for the course content studies had at their disposal our knowledge within the rather generally agreed-upon sources of curriculum: the needs of the learner, the needs of society, and our heritage of culture (the body of knowledge in the form of facts, generalizations, principles, attitudes, arts and appreciations, and applications) from which to draw in creating the educational program for those to be educated.

A reasonable appraisal of the concerns and efforts of those directing the course content studies in the subject field identifies two particular types of effort in each of the various programs:

1. A clear commitment to the concept of learning science through planned investigations of original (problem-solving, discovery, or inquiry) nature.
2. A fresh study of our cultural heritage in the science subject fields with a veiw to bringing the information up-to-date and the searching out of new and more defensible schemes of organization of the body of the content.

Both efforts have been refreshing; the former had been called for by Franklin, Burke, and Priestley in the eighteenth century, Louis Agassiz and Thomas Huxley in the nineteenth, and John Dewey in the twentieth century, all identifying this essential aspect of the teaching of science. This renewed view, which had not been found in college science teaching heretofore was most welcome in the secondary school. The second effort applied to the quality of reading materials in the separate sciences at both the school and college levels. The recounting of factual information in the college textbooks, for example, had been initiated in those prepared for school use, particularly for the secondary school sciences. The general design in both was that of a comprehensive coverage of the field insofar as possible--the pace being set by the textbooks for the first course for each of the college sciences. This pace, somewhat reduced, had been accepted as appropriate for the corresponding secondary school sciences, with a rather generally accepted view that the secondary school science course had as its chief function the preparation of high school pupils for later work in college in the corresponding field.

In general these course content studies have prospered insofar as their acceptance by the science teachers is concerned. Unfortunately, no substantial research of note has been produced through them. A few studies produced externally have provided a limited amount of the objective evidence necessarily produced by a disinterested research agency. It seems unlikely that a definitive evaluation of the effectiveness of the studies will ever be made.

The United States Office of Education developed its own efforts to improve the teaching of science in the schools. Noteworthy were the divisions relating to science in the elementary and secondary schools. The efforts were directed primarily to the stimulation of field activity, the provision of greater science teaching resources through the National Defense Education Act, and through the increase in personnel in the various states with competence and responsibility for improvement of science education in the separate states.

In this period of time, various scientific and professional organizations, each in its own way, directed a portion of its energies into the field of science education. The National Association for Research in Science Teaching intensified its interests in stimulating research. Measures were initiated to improve the quality of the research as well as to extend the amount. Greater measures were taken to compile the results of the research activity and disseminate them among persons who could use them profitably.

The National Science Teachers Association had increased its efforts through the sponsoring of conferences on the improvement of science teaching, in its publication efforts and through its fruitful plan to increase its membership along with its increasing competence in reaching the membership through publication, conference and convention.

Several industrial companies and foundations came forward to help in the effort to improve the teaching of science and mathematics. In the early years such efforts took the form of scholarships and fellowships, writing and publication efforts, and a limited amount of research. With the entry of the federal government, support from companies and private foundations tended to level off and even decline.

An overall summary and general assessment of the situation led to the conclusion that something greater than the separate efforts of the agencies, associations, and individual persons was needed-some program that would bring together and coordinate the totality of the research and developmental efforts in science education. These separate efforts had demonstrated all too well that lack of planning and coordination resulted largely in duplication of research in some fields. At the same time there were untouched areas; and there has been a lack of communication leading to inefficiency and more seriously to conflict and waste of human and physical resources.

SECTION II

DESIGN OF A PROGRAM FOR THE ADVANCEMENT OF SCIENCE EDUCATION

Paramount in the advance of the field of science education is the improvement of the quality of its research. This improvement will necessarily take into account the strengths of research in science education as well as the weaknesses of such research. It has been commonly acknowledged that the research in the field has been spotty and much of it of almost incidental nature. The design of research studies has been of varying quality ranging from studies of careful conception and adequate safeguard of procedure and conclusion, as well as studies characterized by unsupported assumptions and careless interpretation of evidence in itself not always convincing.

One of the basic weaknesses of research efforts in science education has been the lack of coordination with research carried on by other persons investigating similar problems in the field and research by other persons in fields related to science education. Such activities have the very desirable effect of broadening the base of research in the field, but the weakness must and can be relieved by coordination of effort, by better research design and by more careful interpretation of such research.

It should be possible to develop coordinated research programs in such ways as providing parallel studies in science education and other aspects of the school curriculum. There should certainly be occasion to develop research in science education in some direct relationship to our expanding knowledge of learning theory. Because education is a social as well as an individual phenomenon, it should be possible to develop desirable interrelationships between research in science education and sociological research.

The extension of the research effort in science education in such ways as these requires necessarily some refinement in the concept of research in the field. This broadening of the concept of research in itself in turn serves to improve the quality of the research effort and to remove certain of the basic weaknesses of research that have been identified.

The improvement of the quality of research in science education in itself must be followed by more effective development of educational programs that will take advantage of the research product. This more effective development necessarily depends on the ready availability of the research results and a better integration of the research products.

The availability of the research results has been carried forward through the heroic efforts of many persons and the work of the U. S. Office of Education and the National Association for Research in Science Teaching.

Such work has come after the fact of the completed research with little or no opportunity to take part in the development of research design or in the coordination or research efforts. Much needed in the implementation of an improved program for abstracting and retrieval is a communication system based upon a more uniform terminology and more adequate and valid abstracts.

The retrieval of stored information of research nature is a complex problem. The retrieval should have the qualities of ease and minimum effort and should make it possible to sort out the pertinent research product from that which is not pertinent. Ready communication of such information from producer to user is a paramount need.

The availability of all substantial research products needed in a given enterprise or investigation places upon certain agencies the responsibility to translate these products into action programs for the user of the research. Such activities as demonstration and development are of paramount value. The development may take the form of curriculum at some level of instruction, or it may take the form of teacher education to improve competence in the use of the developed material, or in the testing and demonstration of the research product itself.

Such action programs as they may be developed by professional organizations, agencies of the government both state and federal, and by teacher education institutions can make a unique contribution to the advancement of science education in its various phases. Implicit in this advancement is cooperative effort toward common objectives and causes facilitated by communication among those agencies concerned with the advancement of the field and those agencies intimately and directly responsible for and concerned with the educative process. As a result of the social and economic factors previously identified and following upon the growth of understanding as to means of improving education, it has become evident that a central effort supported by various institutions and agencies seems to hold the promise of a solution adequate to the field.

SECTION III

INITIATING A COORDINATED PROGRAM

The need for improving the quality of research in the field of science education has become increasingly evident. The needed improvement became apparent in such specifics as the following:

1. Problems of social significance and problems of professional significance face science education. Research of the highest quality must be devoted to such separate emphases and to those problem situations having interwoven social and professional implications.
2. Insufficient attention has been given to that dimension of research in science education which reflects both the academic and the professional components of the field--the scientific and the educational. The research should reflect increasingly the interrelations of the two components as together they improve the curriculum and the instructional processes to the benefit of the individual learner and of the social group.
3. Improvement of the design of research in science education is a critical factor. This need ranges from that of more adequate conceptions of essential range with the necessary and available processes to that of more limited scope with the particular techniques to be applied.

The need for the coordination of such facets of research efforts is obvious in the face of the basic problem of improving the quality of the research product. The solution of that problem leads but to another:

The distribution and dissemination of research results is a difficult aspect of a coordinated program. It is accompanied by several related problems. Among these are the following:

1. There is much research-related information in science education needed by and useful to consumers of research, but its accessibility is not always assured.
2. Various learned reports of outstanding quality are needed by researchers in science education and by the consumers of research in this field but, because of past review, abstracting, and retrieval practices, have not been readily available. These reports serve to provide background and related information, stimulation, perspective, and to help open up new fields.
3. The dissemination of the research product is useless in those instances in which it falls on barren soil. The potential user may not recognize its significance, or may not know what to do with the product once he has it. He may be faced with a school system or a school community that can not or will not

make an effort to capitalize upon new knowledge or new competence.

Clearly such complicating factors, as well as others, support the need for instituting a coordinated program. Basic conditions for such coordination are adequate communication and designed patterns of effort directed toward common goals in the research program in science education.

Many persons and several organizations have striven to solve or reduce the foregoing problems and to establish programs that would provide a basis for positive action. One of the more successful efforts has been the program of the National Association for Research in Science Teaching.

As interaction developed among interested persons from colleges and universities, from professional organizations, and from federal agencies, it became increasingly clear that interinstitutional and interorganizational cooperation would be prerequisite to the solution of such limiting conditions. The provision of the needed personnel, facilities, resources, and working relationships adequate to the production of a marked impact on educational research and practice is obviously a broad and cooperative enterprise, one which requires substantial financial support.

Discussions related to the development of cooperative activities usually identified the need for organization and mechanisms which would provide coordination for various individual and group efforts. By early 1963 many persons were expressing interest in developing cooperative efforts, well planned and coordinated.

During the fall of 1963 personnel from the Center for Science Education at The Ohio State University began the development of a conference program that would bring together science educators, research specialists, representatives from organizations having a close relationship with activities in science education, and representatives from The U. S. Office of Education. Discussions were held with personnel from ten institutions with strong research programs in science education, personnel from the National Association for Research in Science Teaching and from the National Science Teachers Association. As a result of these informal discussions a proposal was developed requesting support for an exploratory conference involving science education representatives from twenty institutions and official representatives of the National Association for Research in Science Teaching and the National Science Teachers Association. The proposal was submitted to The U. S. Office of Education on June 25, 1964.[1] The proposal received official approval on May 19, 1965, and was funded for the period from June 15, 1965 to June 14, 1966.

With the approval of the proposal the project staff was identified. Two members of the faculty of the Center for Science Education at The Ohio State University, Professors John S. Richardson and Robert W. Howe, served as Director and Co-Director.

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[1] Richardson, John S., and Robert W. Howe "The Role of Centers for Science Education in the Production, Demonstration, and Dissemination of Research." U. S. Office of Education Project No. Y-002, June, 1964.

The project staff initiated early measures to gain an assessment of the resources of the field for research in science education. Only through such an assessment can the potential be estimated; a further benefit lay in providing a basis for the identification of an additional ten institutions with strong research potential to be invited to the initial cooperative effort and to the conference.

With the assistance of the Advisory Committee, the project staff studied the professional resources represented by the science education faculty, analyzed the programs and resources of institutions that are active in research in science education. The evaluation was based on information from a survey identifying and analyzing the resources, professional activities, and potential and actual productivity of the centers for science education. Site visits of the centers in selected institutions were made by the Director and Co-Director. An invitation was issued to the appropriate dean in each of the identified institutions, requesting the appointment of an official representative. A complete list of persons who attended the conference is provided in the Appendix.

The format for the conference was developed, so designed as to provide discussion and debate of several papers presented by consultants and other professional personnel. This planning culminated in the development of a plan for action to strengthen and to improve activities in science education. To initiate such a plan, a conference of the institutional, associational, and governmental representatives along with consultants was essential. With the development of the program, consultants were identified and invited to prepare the present papers devoted to the following areas:

Analysis of Strengths and Weaknesses in Current Research in Science Education	Ralph W. Tyler, Director Center for the Study of the Behavioral Sciences
Resources, Models, and Theory in the Improvement of Research in Science Education	Ralph W. Tyler
Research in Issues and Problems Through the Resources of Science Education Centers	Stanley E. Williamson, Chairman Department of Science Education Oregon State University
Centers for Science Education: Functions and Designs	Robert W. Howe Co-Director, Conference Program Associate Professor Science Education The Ohio State University
The Center for Science Education in Changing Educational Practice	Addison E. Lee, Director Science Education Center University of Texas

Strategies and Dynamics in Changing Educational Practice	David L. Clark Professor of Education The Ohio State University
Some Guidelines for Research Design and Action	John S. Richardson Director, Conference Program Professor of Science Education The Ohio State University

Following the presentation of each of the major papers, a period was devoted to questioning, elaboration by the speaker, and group deliberation. Following the consideration of and deliberation upon each paper, small group discussions (four to six persons per group) provided additional opportunity for analysis, criticism and extension of the ideas and proposals presented. The papers are included here within Section IV, page 13.

A summary and synthesis of individual and group reactions to the papers and of the recommendations emerging at various points are presented in Section V, page 113.

SECTION IV

PAPERS PRESENTED AT THE CONFERENCE

ANALYSIS OF STRENGTHS AND WEAKNESSES IN CURRENT RESEARCH IN SCIENCE EDUCATION

Ralph W. Tyler
Center for Advanced Study in the Behavioral Sciences

APPRAISING CURRENT INVESTIGATIONS

During the past few weeks, I have been able to review the abstracts of research in science education appearing in the United States Office of Education reports for 1955 through 1961. Our hosts also provided me with abstracts for many of the studies completed during the past five years. A critical appraisal of these investigations clearly indicates that the thoughtful evaluations made by William W. Cooley and by Kenneth E. Anderson in analyzing research in the teaching of science published in the period July 1957 to July 1959 are also largely applicable to the most recent studies.

After pointing out some of the inadequacies of present research, Cooley writes "Such technical shortcomings are, however, merely the result of fundamental difficulties. One of these difficulties is the fact that we seem to have to rely almost exclusively on degree candidates to conduct the research. . .Such research is necessarily hurried and harried. . . Another fundamental difficulty arises from the fact that we often attack issues or problems head-on, without sufficient attention to the framework underlying them. . .finally, a third fundamental difficulty is the fact that our discipline does not now possess a definite structure of criticism. If research is conducted in an area where naive and inconclusive work is published along with the good, and if poor work goes uncriticized, improvement can hardly be expected."[1]

Anderson comments on the weaknesses of research in the teaching of science both in the problems and content selected for study and in the inadequate qualifications of those conducting the investigations.[2] He states: "Our research workers in science education must be so trained that they:

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[1] E. S. Obourn, P. E. Blackwood, and M. J. McKibbin, Research in the Teaching of Science, U. S. Department of Health, Education, and Welfare Bulletin No. 2. Washington, D.C.: U. S. Government Printing Office (1962), 4-10.

[2] Ibid, 11-22.

(1) are well-grounded in their academic fields, (2) know the academic areas related to and important to education, (3) know the psychology of learning, (4) are sophisticated in the application of research and statistical methods to problems in educational fields, and (5) will be given an opportunity to pool their resources in an interdisciplinary effort via a research center."

In my own review I found that not more than ten per cent of the most recent studies meet what I would call reasonable, technical criteria. Attempts are made to generalize findings from populations poorly defined or not defined at all. Where the problem of sampling a population is recognized, few studies use modern principles of sampling. Variables are ill-defined, measures of them are often of low validity and techniques of analysis and interpretation seem to be done by recipe rather than to have been selected in terms of the applicable conditions. But these technical inadequacies are less distressing than the weaknesses in the content and the logical structure of at least four out of five of the studies reported during the past five years.

About one-fourth of the investigations sampled were fact-finding surveys with no attempt at generalization, although this might have made some of them useful beyond the situations they represented. Some facts are needed in planning and conducting a program of science education, but, like the decennial census, the collection and reporting of facts alone is not research. It may be helpful to know that one-fifth of the schools in a given state teach certain topics in biology, but unless this fact is part of a larger context from which generalizations can be made, it does not provide a basis for understanding significant elements in science education, nor for planning and conducting better programs.

Another fraction of the studies examined, about 20 per cent of them, were collections of opinions about the values of topics, objectives, courses, equipment and facilities, and ways of teaching. Such investigations can provide facts about what people believe, but, in themselves, they are not bases for generalizations.

The largest number of investigations, more than 30 per cent were attempts to study the comparative values of different courses or different methods of teaching. These studies treated courses and methods of teaching in such large categories that, typically, the variance in achievement within classes using the same course and classes using the same method was as great or greater than the variance between courses and methods. An experienced observer knows that the title of the course or the textbook covers a wide range of actual teaching-learning operations. Similar wide variations are noted in such categories of teaching methods as lecture demonstration, textbook recitation, individual laboratory work, and so on. Most of these studies did not involve clearly defined variables from which meaningful generalizations could be drawn. Furthermore, most of them did not employ achievement measures that clearly appraised the progress of students toward the objectives stated. Except for the null hypothesis, few of the studies provided useful conclusions. Even where the null hypothesis is accepted, this might mean that the independent variables were not distinctly different,or that the measures used were not focused on the actual learning of the students or it might mean that some of our new courses and some of our so-called teaching methods do not greatly influence what students gain from their study in science.

Few of the reported investigations represented systematic research relating to the objectives of science and fewer still dealt with theories of learning compatible with different objectives of science teaching. The sequential development of a science program was an area of study in several of the reports, but in all but one these were efforts to assign grade placement to topics. Since science is a structured discipline, rather than a miscellaneous collection of facts and generalizations, grade placement can be undertaken only in terms of sequences and not in terms of individual topics. None of the investigations conducted empirical tests of sequences in one or more of the sciences.

The integration or interrelationships of concepts, generalizations, and/or methods of inquiry of two or more sciences was a subject of study in only one of the investigations reported and this gave meaningless results because no effort had been made to identify possible interrelations. Instead, the study simply reported that when chemistry and mathematics were taught in the same course, students scored as well on tests in each subject as when the courses were taught separately.

The studies of pupils generally used gross variables such as previous grades in science, IQ, personality test scores, interests in science. In only two cases was there a clearly developed conceptualization to indicate why any of the measures used might relate to learning in science courses. Most of the studies of teachers also employed gross categories like college majors, number of credit hours in science, years of teaching experience.

Another serious deficiency is the short time span covered by most of the investigations. Of course, not all research studies in education need to extend over months and years, but some do. Most educational objectives require a long time for development and the expectation is that what is learned will become a permanent part of the individual's repertoire of behavior. Hence, some research requires long-term studies of development and retention.

After reviewing these reports, I certainly share Cooley's view that the potential value of research for improving science teaching is not being realized and a considerable explanation seems to lie in the lack of a cadre of professional research people deeply concerned with research in science education, who devote major time to this work and who among themselves and with scholars in other fields are seeking to gain greater perspective, more adequate conceptualizations to guide their study, and better instruments for research. This should help also to correct an obvious current fault, namely, the failure to build a systematic structure on which new findings may continually be added enabling scholars both to refine earlier knowledge and to reconstruct the whole into a more adequate conceptualization.

DEFINING RESEARCH

Up to this point, I have been reporting appraisals of current research without explicitly defining research or criteria for judging examples. It is not easy to get agreement on a definition of research which is sufficiently inclusive to cover historical, philosophical, analytical, and experimental studies and at the same time limit the definition to research investigations while excluding works that are merely assertions, speculations or expositions of doctrines. Perhaps the most acceptable definition of research is systematic study in which the major generalizations and the bases on which they are made are publicly reported in such a way as to permit independent verification. This definition can be applied to historical studies in which sources of data are given and the basis of the inferences drawn are also reported. Similarly, the logical and/or the empirical bases for philosophical and analytical studies are fully reported if these studies are to be considered research. In the case of experimental investigations, the description of the subjects of the experiment, of the experimental procedure, and of the methods of collecting and analyzing the data furnish the information required for independent verification. Research as thus defined is likely to be superior to common sense statements because the study is more systematic and the intellectual processes together with the information obtained and used are made public for criticism and independent verification by others.

The object of research is generalization, that is, the discovery of or the formulation of something which has wider applicability than a description of the particular case or cases which were the subjects of study. For example, in a 1961 analysis of the scores of science teachers on a test of methodology of science, it was reported that "the mean score of the 1,268 science teachers who took the test was 15.95. This was 13 raw score units below the mean score of 28.95 achieved by the 57 undergraduate students currently completing a course in the philosophy of science." This finding merely summarizes the data from these 1,325 individuals; a research study seeks to establish more general findings. By choosing the teachers so as to be representative of a larger population and the undergraduate students, and by taking appropriate measures of the variations in the mean scores, it becomes possible to make a general statement about the difference in mean scores between science teachers and undergraduate students likely to be found in populations of the sort described. This is an example of generalizations derived from investigations that are beyond the particular objects of the study.

Because sound research affords generalizations applicable to other cases, it is helpful in understanding and dealing with new situations with which we are confronted. For instance, many research studies have shown that the correlation between high school grades in science and college grades in science for students in public schools enrolling largely middle class children is higher than that between scores on standardized tests in science taken in the high school and college grades in science. It has also been shown in at least one investigation involving interviewing such students that the majority view both school and college as systems which they must master. They attent to the teacher's expectations more than to the materials of instruction and the success toward which they work is a certain grade. Such research helps us to understand something of the learning process when rewarded by teacher's grade.

We can state generally that the function of research relating to education is to provide a basis for understanding the educational process or parts of it and for planning and developing educational programs. It is important to note that educational research rarely provides a specific question about an educational practice. Much more often, research provides a basis for practice in terms of the concepts it furnishes the practitioner, the outline it formulates of the dynamics of the processes with which the practitioner is concerned, and the relations it establishes among the concepts and the estimates it provides of the parameters of the dynamic models that are proposed. That is to say, the value of research lies in providing the practitioner with broader and more detailed maps of the terrain of education with which he deals. With better maps, we are better able to find our way, and reach our goals. Concepts, dynamic models of processes, relations among concepts, and quantitative estimates of the effects of various factors in these models are in some respects the equivalent of maps.

The need for more adequate maps of the terrain in which we work grows out of the complexity of the various processes involved in education. Systematic and orderly investigations of complex phenomena require conceptualizations; i.e., views of what to look for,how to look for them, and what kinds of structures, processes and relationships are involved. When one enters a classroom, if he had no prior conceptualization of teaching and learning, he would see children and an adult, he would hear several children and the adult speaking, he would note physical items in the room, movements of people and the like. What gives it meaning for the teacher or for the investigator of classroom instruction is a model which he conceives, a simplified picture of the structure and process of classroom instruction. This model usually includes such elements as a teacher, pupils, objectives of instruction, methods of teaching, materials of instruction, and learning outcomes. If he holds such a model in mind, he has a basis for guiding instruction or for focusing his observations and for arranging and analyzing his data. This development of a formal model provides a way of viewing the complex phenomena in a fashion which permits scientific study. Models serve to simplify a process which appears on the surface to be too varied or complex or haphazard to be understood. But models must not only simplify complex phenomena; they must provide a means for explaining and predicting the variations and regularities observed in the phenomena. Hence, conceptualizations change as research indicates that earlier models fail to explain or predict many of the observations noted. For example, a common model for research in instruction in the 1920's included a teacher, a group of pupils, methods of teaching, and learning outcomes.

This conceptualization recognized variations in the intelligence of pupils, various methods of teaching and variations in the degree of achievement by the pupils of the learning outcomes. Since that time, a number of things have been added to this model such as variations in the initial achievement of pupils, in the kinds of pupil motivation, in the content and intensity of pupil interests and variations among several major kinds of educational outcomes, such as knowledge, skills, attitudes, and problem solving. Effective educational research is commonly guided by and requires the selection or formulation of conceptualizations which provide ways of viewing the complexity of educational phenomena in orderly and meaningful patterns.

In providing better maps to guide the efforts of practitioners, we have been greatly aided by the scholarly work of those in other disciplines as well as by those who are primarily concerned with education. For example, the social psychologists' work on small groups has noticeably influenced educational research. Increasingly studies of personality development in children and youth in school and college, and studies of successes and failures in educational achievements are analyzing the peer groups to which the pupils belong; some peer groups provide reinforcement for the learning emphasized by the school, other peer groups may insulate its members from school influences, while still other peer groups may operate to teach values and practices in opposition to the school objectives. Furthermore, some research in classroom instruction has involved experimentation with small groups as units for teaching and learning. A class of thirty or forty may be reconstituted into several groups of from three to eight members each group assuming responsibilities which require group planning, group attack, group review and appraisal, group discipline and group rewards. It is hypothesized that such learning experiences will have great influence if each group becomes well-integrated and concentrates its attention on the job at hand.

Social psychologists are also suggesting the importance of perception as a factor in behavior, particularly in learning. How one reacts to a given situation is largely determined by what he sees in that situation. Furthermore, one's attitudes are, in considerable measure, shaped by his perception. How he feels about persons, objects or events is greatly influenced by what he sees in them, and several persons looking at the same phenomena will often see different things. Present evidence indicates that one's perception of objects, persons, or events takes shape in the early contact with them and remains fairly stable in spite of many later opportunities to check the inadequacies of the early perception. The early perception is often formed by the suggestions of others as well as by one's own careful observation. Thus, children may early develop the notion that the sea is blue, partly perhaps from observing it when it was blue and partly by the suggestions of others, as in paintings. It is found that most children continue to see a blue sea even when asked to observe it when it is clearly gray, brown, or green.

Or, to cite another example, children may at an early age develop the notion of a butcher as a fat, jolly man. This perception often continues to operate even when children are asked to observe butchers who are, to an objective observer, lean and dour. Perception of both physical and social phenomena is quite likely to be stereotyped in spite of many opportunities for correcting the inadequacies of earlier perceptions. Since one's behavior is strongly influenced by what one sees in the situation, and since much of what one sees is the memory of an earlier perception, reactions to situations are often unrealistic because one's perception is unrealistic.

The importance of this concept of subjective perception for the planning, conduct and interpretation of educational research is only currently becoming recognized. Frequently, studies of curriculum and instruction will need to include data on the perceptions of pupils regarding the objects of study, the learning task, the teacher and other pupils, and perceptions of the teachers regarding their purposes and their pupils. Studies of guidance may also need to include data on how the pupil is perceived by other pupils, by teachers, and by guidance counselors, how the guidance counselor perceives his task, how the pupil perceives his task, and how the pupil perceives the activity and the persons involved in it. Studies of administration and of teaching personnel will also find this concept helpful.

As a third illustration of the contributions of research people in other disciplines, those of the sociologist are noteworthy. Probably the most widely used sociological conception in education is that of social stratification. Every society or large-scale social organization is conceived to be composed of several social classes, that is, collections of people of a similar level of social prestige and public respect. These several strata of society are commonly found in each town and city, with the social classes corresponding roughly to income and occupational levels. From the standpoint of their influence on human behavior there are two major characteristics of this social class structure: (1) each social class sets a pattern of conventional or acceptable behavior for its members, and (2) the hierarchy of social classes in terms of social prestige or public respect forms a ladder to direct the actions of members of a lower social class who seek to rise in public esteem and social recognition.

The pattern of acceptable behavior in one social class differs in various respects from that of another. Among children of lower classes, fighting is an approved form of behavior. The use of certain four-letter words is acceptable in some classes and not in others. Sharp differences in etiquette, dress, table manners, and the like are noticeable. Many parents in lower-middle classes desire higher prestige for their children. They often find cues for educating children for upper-middle class roles by observing the models of middle-class behavior shown in movies, television, radio, magazines, newspapers and the like. Thus, the hierarchy of social classes exerts a powerful directive influence on those who seek to climb the social ladder.

Social stratification is a concept that has already had considerable influence upon educational research. For example, the past fifteen years have witnessed the inclusion of social class as a major variable or category of analysis in studies involving school children, teachers and communities. The concept has made us conscious of the inadequacy of some of our previous notions about the educability of particular individuals and groups of children. The vocabulary, the kinds of problems used and the accepted behavior of the schools reflect the middle class, old American culture. Children who come from other groups employing different vocabularies, accustomed to different patterns of behavior find the typical classroom confusing and the classroom activities difficult to carry on. They are often judged to be mediocre or slow learners and are frequently advised to attempt only the required minimum of formal schooling. Yet, studies of problem solving among various social classes indicate a considerable number of children and youth in every class who are adept in attacking problems when the problems are real to them and couched in their language. So there is an increasing interest in identifying kinds of learning experiences which are meaningful to pupils from lower social classes and which can help to increase the effectiveness of the schools in working with these children. There is also interest in devising tests that may serve as better indicators of the educability of lower-class children than do the current tests of scholastic aptitude which largely include middle-class vocabulary and problems.

Viewing the contributions of educational research of the practitioner in terms of providing better maps of the terrain in which the practitioner is engaged does not rule out research investigations which provide direct answers to operational problems, but the amount of the latter research is small. Because of the complexity of educational processes combined with the artistic adaptations which teachers and administrators make in the use of principles, materials, and procedures, it seems unlikely that a large fraction of educational practice can be guided by precise specifications. But, the value of maps in guiding practice must not be overlooked nor underestimated. Our conceptions of the important features of any particular task are necessary to guide our actions. The better these conceptions are the more effective we are likely to be in planning and executing the task.

CRITERIA FOR RESEARCH

On this background of analysis of the contributions of research to education, I should like to suggest three major kinds of criteria for research: (1) relevance, (2) adequate conceptualization, and (3) sound methodology.

Relevance seems an obvious criterion and, at first glance, it might appear that all research that has to do with schools or colleges, pupils, students, teachers, professors, or school administrators is relevant. But education is more than schools, students, teachers, and administrators. It is an enterprise conducted to attain educational ends, that is, the educational process is learning directed toward desired goals. The educator is seeking to help students learn ways of thinking, feeling, and acting which represent the objectives of the school. Studies in which children are learning kinds of behavior very differently from the behavior sought as an educational goal can be misleading; because the fact that learning is an object of study may prevent the practitioner from noting the respects in which the learning being investigated is so different from the learning attempted in school as to be irrelevant.

Or, to take another illustration, research on science supervision which assumes that the teachers are primarily directed by rules, regulations, and instructions is irrelevant to education, where the teachers cannot effectively be given specific instructions and the coordination and unification of the efforts the various teachers develop from their sharing an understanding of and commitment to common purposes. The actual procedures of each teacher are his interpretations, sometimes creative ones, of the ways in which he can best attain the common purposes through his teaching efforts.

Because the activities of teaching are not mechanical but are the expressions of the teacher's conception of the job to be done and how to do it, research which fails to consider what teachers are doing is generally irrelevant to the problems of improving education in the schools. A method of teaching is not defined except as it is expressed in the ways in which teachers initiate activities with children and respond to the various efforts the children make.

Because a good deal of research in education includes important aspects which are not appropriate to the educational situation, the question of relevance needs to be continually raised. In what important respects are the objects of this study similar to an educational situation? Can this study be made relevant or should it be dropped or ignored? Since time and energy are limited, a logical place to focus effort is on relevant investigations, seeking to represent in the research one or more important factors in the educational process.

A second kind of criterion relates to the conceptualization of the phenomena being investigated. What are the basic concepts on which the research investigation is planned and interpreted? What is the justification for those that are used and for those that are left out? Have they been substantiated by previous research in this area? Or, are they concepts which are accepted as sound by the scientists and scholars in some other disciplines? Or, are they concepts which are logically possible and are tested for their relevance and usefulness in the present investigation? Similar questions should be raised and answered regarding the conception of the dynamics of the process or processes with which the investigation deals. The relations among the concepts and the parameters for the factors in the dynamics also need to be scrutinized if they are involved in the research. It seems strange that many research reports give no explicit statements regarding the conceptions of maps of the terrain that are employed to guide the investigations. The conceptions can be teased out and constructed, but the writers of the reports too often seem to assume that everyone uses similar conceptions or that the conceptions are not important in determining the meaning and significance of the research. This is a mistake. The conceptions used to guide the research are critical in determining what the findings mean and their value for practice in any particular case.

As an illustration, consider the typical study of the prediction of student success in college. These investigations commonly obtain one or more measures of the student prior to college entrance, such as, his average grade in academic courses in high school, his score or scores on scholastic aptitude tests, and correlate these measures with his grade-point average after one or more terms in college. Such a study employs only a few major concepts, such as average grade in academic courses in high school, scholastic aptitude, and college grade-point average. The conception of the dynamics of college success is one in which the influential variables all lie within the individual student. The college experience is treated as a constant and the college grade-point average as a dependent variable.

It is quite clear that other conceptions are possible and may be more useful for understanding the dynamics of college education. For example, the behavior of college teachers and/or the peer groups with which the student becomes affiliated can profitably be examined as a basis for understanding college success. Another, somewhat off-beat conception places the major factor in college success on the college teacher. Those students to whom he gives acceptable grades and considers successful are those he is able to teach, those he fails are those he is unable to teach. In such a conception, success or failure of the student is simply a term given to indicate the effectiveness or ineffectiveness of the teacher. This illustration indicates the value of examining the conceptualization of research studies since inappropriate and inadequate conceptions cannot provide findings that are appropriate and adequate.

A third type of criterion to apply to educational research has to do with methodology. This includes the means used to select the specific examples for study, the methods employed to obtain relevant information and data and the procedures utilized in analyzing and interpreting the data. With regard to selecting the specific examples for study, the questions are: Are these cases likely to provide examples of the phenomena to be investigated? Are these cases representative of a population about which generalizations are to be made? Is the number of examples chosen for study adequate to reveal significant factors after allowance has been made for chance variations?

With regard to the methods employed to obtain relevant information and data, the questions are: Are these methods valid, that is, will they actually provide measures or descriptions of the phenomena desired? Are the methods objective, that is, will two competent persons using the methods obtain similar results from the same cases? Are the methods reliable, that is, will the results be sufficiently stable to make the generalizations sought after allowance is made for chance variability in the measures or descriptions? Are the methods sufficiently accurate to provide the degree of discrimination among different measures required to derive the kinds of generalizations sought?

With regard to the procedures utilized in analyzing and interpreting the data, the questions are: Are these procedures appropriate for the kinds of data? Do the procedures take into account all of the data or do they concentrate on portions of the information to the neglect of others? Do the procedures allow for the unreliability and inaccuracy of the data? Do the procedures meet the normal canons of logic? Do they provide independent checks on the soundness of the generalizations?

These are general questions which should properly be asked about any methodology employed in research studies. However, the answers to these questions require an understanding of specific research methods of which there are many. Hence, I shall not attempt to elaborate this criterion with examples, but hope that each of you will bring illustrations to bear from your own special field of interest and experience.

Illustrations of the Criteria

With these three kinds of criteria in mind, relevance, adequate conceptualization, and appropriate methodology, it may be helpful to review an area in which a good deal of educational research is now being conducted. One of these areas is the development and improvement of the curriculum. With the aid of federal funds, a number of massive curriculum development projects are under way, particularly in science and mathematics. It would be easy to suggest that what is needed now is to evaluate these new programs and materials to determine whether they are really an improvement and particularly whether they are appropriate for the wide range of young people who attend the public schools. In many cases, it is thought that some of these curricula have been developed primarily for the more able students or the college bound. How far they serve other groups of students is a question for research. In some of the projects, there is now a conscious effort to develop materials for students who are not college bound. For example, the Biological Sciences Study Committee is now preparing a biology course for slow learners and the School Mathematics Study Group is working on a course in mathematics for youngsters with limited mathematical background. Although some of the projects recognize the problems involved in educating the total range of ability that is represented in our schools, some do not. Hence, it seems obvious that what is needed in many of these projects is research to find how far various types of students really learn what is being taught. However, this is not as simple as it sounds, because many of these new courses emphasize objectives which are different from those we have been appraising in the past and some of the courses are based on different theories of learning and different notions about the conditions for effective learning.

The new curricula are not simply the earlier ones brought up to date in terms of more recent knowledge, but in many cases they also represent a marked shift in the nature of the educational objectives being sought and the theories of learning on which instructional materials are constructed. This is not to say that none of the curricula to be found in the schools prior to 1958 was similar to the new ones, but rather that the prevailing textbooks and curriculum guides in many fields in the pre-Sputnik era emphasized different objectives and utilized different theories of learning from those found in the new curricula. One of the chief kinds of objectives given primary emphasis in the new curricula is to help the student develop into a lifelong learner, a person who is continually making inquiries into questions in this field. Facing the fact of the rapid change taking place in knowledge, particularly in scientific knowledge, it is impossible for the student in school to acquire adequate understanding of problems he will face twenty years hence. Therefore, if he is to deal intelligently with problems he will encounter in adult life, he must keep up his efforts to learn throughout life. This means that the school curriculum must develop some skill in learning, interest in continuing one's learning and the habit of continued study. These are important aims. In attempting to attain them, the new courses greatly reduce the amount of specific content covered and give primary attention to a smaller number of units in which the student actually carries through illustrative inquiries, studies appropriate to the student's maturity but still faithfully reflecting the methods and spirit of the subject. This selection of illustrative units for careful study is done to provide sufficient learning of the ways in which questions are investigated so as to provide some assurance that the student can continue to learn rather than attempting to cover everything of importance in the subject.

A second kind of objective emphasized in these new courses is to help students understand the structure or organization of the subject. It is obvious to intelligent adults that each subject has a structure, that it is an organized body of material. It isn't just a miscellaneous collection of facts, notions and terms, and so on, which are to be memorized with the expectation that the student will be able to recall the items as he might the numbers in the telephone book. Because each field has an organization, its elements can be more easily grasped than if it were unorganized. In a science, for example, the subject is organized in terms of the kinds of questions with which it deals, the sorts of phenomena which it studies, the kinds of concepts it uses to make meaning out of the questions and data, the sorts of methods it uses, and the kinds of generalizations it formulates from its inquiries. These give a structure to the subject, and persons can learn more effectively and efficiently in this subject as they acquire understanding of the structure than by trying to memorize a lot of specifics without seeing what the organization of the subject is.

This idea of structure or organization serves not only as a major kind of objective in teaching, but also implies a theory of learning for it is not consistent with a specific stimulus-response theory.

A third type of objective in many of these new courses is to learn to use the subject as a tool of thinking, feeling and acting, a means by which to learn more, to guide one's actions and to get increased satisfaction and feeling. The emphasis is upon the active using of the subject rather than upon passively remembering or acquiring and depositing facts and ideas from it. The subjects are to be viewed as tools to help one to feel, think, and act, rather than subjects that give answers to how one should think, feel, or act. This may seem like a small difference, but it is important. In the social sciences, for example, many parents and some teachers think that the subject tells a child how he should act, how he should vote, what he should believe, rather than treating it as a tool by which he learns to carry on his thinking about social issues, and helps him in guiding his actions in connection with social issues, and in understanding more clearly the relevance of attitudes to ways of living. Or, many people think of the natural sciences as giving answers to questions rather than a way of seeking to understand and to explain phenomena ever more adequately but never completely. In these three ways, the objectives of many of the new courses differ from many of the old.

The new courses also differ in the theory of learning which has been followed in their development. Not all of the new courses are based on the same theory of learning, but many of them are planned in terms of "learning by discovery," which is a kind of inductive learning. The materials are designed to help the youngster develop concepts and see relationships through observing phenomena and reflecting upon what he has observed. This is in contrast to naming and defining concepts and generalizations first, then asking the learner to verify them or to find illustrations.

These few illustrations will suggest the ways in which many of the new courses differ from earlier ones, particularly with regard to objectives sought and the kinds of learning which they attempt to facilitate. Meaningful research relating to these curriculum developments must be relevant to the objectives and the kinds of learning sought. But beyond this the research should employ adequate conceptualizations of the educational processes involved in the utilization of these new courses. The course and the students are not the only major factors in the process. What the teacher is trying to do and what the students think they are trying to learn are also important. Hence, research is needed to assess the understanding of the teachers and students as to the objectives and learning experience involved in the new courses.

I have visited a number of classrooms where the new curricula are being used and I have found a wide variation in what is being done and in the ideas of teachers and students about the new courses. For example, I found various classes using the new physics course where the teacher was very conscious of what the objectives were, what the theory of learning was, that the exercises were samples of inquiry and were not supposed to be a catalogue of things to be memorized. On the other hand, I found classes, using the same materials, claiming to be the new physics course in which the teacher had no notion that this course was any different from older courses except in new content. He viewed the materials as presentations of facts to be memorized just as he had used the older physics textbooks. He did not understand the objectives nor the learning theory involved in the new course. Hence, to understand the successes and the problems of the new curricula, we need studies of the conceptions teachers have about the new courses they are using to find out the extent to which they understand the new curricula. Then, we need studies of what actually goes on in classroom and laboratory to estimate the extent to which the new curricula are actually being followed. I noted, in my visits, that some teachers who understand, at least verbally, the course objectives and plans for student learning, are unable to modify their own habits sufficiently when they get before a class to carry on the instruction in the spirit of the new course. There is sometimes a difference between the teacher's understanding and his actual teaching performance.

The conceptions and the learning activities of students should also be studied in order to determine the extent to which courses as conceived and planned and are actually being carried out. When I was at The Ohio State University, work was undertaken on new biology courses at the college level. The emphasis in the new courses was on problem solving rather than simple memorization. The project was quite successful in getting the teachers to understand the objectives and the learning theory. They worked out the exercises used and they participated in a general seminar which developed the theory and plan. However, the students came into these courses from a background which was very different. They had been memorizing material from several textbooks. They were flabbergasted to have a course that demanded something that they were not accustomed to before. It required special effort to change the students' conception of what was expected of them in these biology courses. In the current situation, we need to investigate the conceptions of students about the objectives of new courses, and how thev carry on their learning activities. Furthermore, we need studies of the way in which students are using what they learn. Research of this sort is necessary to find out how far these curriculum reforms are anything more than paper programs, how far their purposes and plans are being reflected in teaching and learning. This is an illustration of the way in which an examination of the conception of research suggests more adequate bases for the investigations.

The consideration of methodology in these curriculum studies may best be illustrated with the instruments used for assessing student learning. We need to develop appropriate measuring instruments for the objectives of the new courses and for the range of children and youth that we have in our public schools. We do not, at present, have very good measuring instruments to indicate to what extent students have gained an understanding of modes of inquiry in the field, have developed interest in continuing their study, and have acquired habits of using these modes of inquiry. Since these are important objectives, we should be appraising school learning in these terms. Furthermore, we need better measures of the extent to which students understand the structure of a subject rather than simply tests of the facts they can recall. The needed measures should be based on a sample of the important concepts and generalizations and relevant illustrations of them, and not involve simply a collection of unorganized items. Furthermore, we need more of the kinds of exercises or evaluation instruments that give us information about the ability of a student to use these things that he is getting from each field in connection with his own life, that is, to use them in his thinking, to use them in his action, and to use them in forming his opinions.

Present evaluation instruments are not altogether satisfactory for assessing the range of pupils now in our schools. Tests we now use have been developed as a means for identifying individual differences. This requires test items which give the maximum differences among individual students which are items with about 50 per cent difficulty for the population taking them. Thus, items are eliminated that approach zero difficulty, that is, that everybody can do, and those that approach 100 per cent difficulty, that is, what very few people can do. This is an efficient procedure in test construction where the purpose is to obtain measures for differential guidance, or to award scholarships for those whose performance is near the top, or where the purpose is to promote some students and not others, or to recommend some students for college admission and not others. In these cases, a selection is to be made among individuals and the measuring instrument is used to identify individual differences among students. But when we are trying to appraise the curriculum by ascertaining how well the students are learning, we need information about those things that nearly all students are learning and those that very few are learning as well as those that are being learned by about half the class. We need to build tests by a different principle when we are trying to evaluate a curriculum than when we are trying to assess individual differences. The questions to be asked about an item for the curriculum are: Is this exercise relevant to one or more of the objectives? Is this exercise something we would expect some fraction of the class to work out? Does this item help to provide a good range of exercises from those everyone should be able to do to those that are likely to be done only by the best of the students?

In general, in such tests, we seek a collection of items approximately divided among those that are near 100 per cent difficulty, those that are around 50 per cent difficulty and those that approach the zero level of difficulty. We have few tests now which meet this specification.

SUMMARY

The function of research relating to education is to provide a basis for understanding the educational process and for planning and developing educational programs. To serve this function research provides concepts and quantitative parameters for some of the factors. These can be used as maps in moving along the educational terrain.

To attain these values from research, the investigations need to meet three kinds of criterion, namely, relevance, adequate conceptualization and appropriate methodology. Research of this sort in the field of science education can furnish the basis for marked improvements in the teaching of science and much greater effectiveness of learning.

RESOURCES, MODELS AND THEORY IN THE IMPROVEMENT OF RESEARCH IN SCIENCE EDUCATION

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INTRODUCTION

In my presentation yesterday, many recent research projects in science education were criticized not only because of technical shortcomings but because of deficiencies in content. I suggested that the primary contributions of research are not in giving specific answers to specific questions, but in providing concepts, dynamic models, generalizations, and parameters for the models that help us to understand educational processes and to plan and conduct educational programs. In these terms, many of our current research efforts are irrelevant, inadequately conceptualized, and methodologically naive.

WAYS OF IMPROVING RESEARCH

The purpose of the paper today is to discuss ways of improving research in science education, but I shall not follow the order of the items in the title. Theory is the all embracing end of basic research in seeking to provide a comprehensive map of the terrain of science education. Concepts are the smaller areas which comprise the total map, or to put the metaphore in another way, the complex of science education can be understood more readily by considering the concepts as major parts of the whole, and studying these parts in greater detail than is possible with the total. Models are the outlines of the dynamic relationships which help to explain the process as an active one rather than an anatomical structure. The concepts and the dynamic models furnish the map which we seek in order to understand the factors involved in, and the processes of science education. They form the major part of the theory. Discussion of the resources will follow later in this paper.

My criticism of current research is its failure to be guided by, or to produce an adequate map of the factors and processes in science education. The missing map cannot be produced over night, but there are concepts and models which have been evolved from earlier research or from other fields that can serve to provide initial areas on the map for more adequate definition, clarification, and testing as to relevance and helpfulness in understanding science education; imaginative researchers can sometimes hypothesize new ones that appear to them to be promising bases for understanding one or more aspects of science education, and which can also be tested as to relevance and helpfulness. The outlining, elaboration and testing of such a map seems to me to be the necessary focus of our attention if we are to improve research in this field. As our concepts and models are found helpful in understanding processes of science education and in planning and conducting programs, some of our major attention can be directed toward translating research into educational practice by developing procedures, materials, and devices that utilize the insights being obtained from research. The lack of this map leads to isolated investigations, opportunistic studies, and short-term projects which have limited relevance to the major problems of a program in this field.

To make this proposal more concrete, I should like to illustrate some of the areas that could furnish initial phases for developing a map of the terrain of science education. I do this with some diffidence because most of you are much more familiar with problems and possibilities in this field than I. But I do hope to afford examples of programs of research attacking recognized parts of the total area in some systematic way. Errors in judgment relevance and in comprehensiveness and accuracy of conceptualization are corrected by the findings of the investigations made.

Among the areas in which the total terrain might be broken for more detailed study are the following eleven: (1) the objectives of science education - What to Teach? (2) the teaching-learning process, (3) the organization of learning experiences, (4) the outcomes of science education - What is actually learned? (5) the student's development, (6) the development of teachers, (7) the objectives of education for science teachers, (8) the teaching-learning process of teacher education, (9) the outcomes of teacher education, (10) the organization of the teacher's learning experiences, and (11) the processes of change in programs of science education. These eleven areas are not all that could easily be suggested as aspects of science education, but they are important areas, and systematic study of them using present concepts and models can lead to a much more comprehensive understanding and a more adequate basis for planning. I shall try to illustrate this assertion briefly.

Research on Objectives

The aims of science education have changed several times during the past half century, changes in goals are appropriate when new possibilities are seen in a field and/or when changing conditions make new demands on people. But it is also possible that new aims are accepted uncritically, without considering their soundness and importance in relation to the goals which are discarded. Several kinds of investigations are needed to provide a basis for decisions about major objectives. The first are studies of the kinds of contributions to the behavioral repertoire of human beings which science is capable of making. We know in general that science is an enterprise seeking to provide an increasingly comprehensive understanding of the world and that this involves attitudes toward phenomena, processes of inquiry which use techniques of investigation and products of inquiry -- concepts, hypotheses, facts, and generalizations. But we do not know how helpful each of these aspects of science can be to the layman who is not a professional scientist, nor do we have a carefully considered analysis of the particular attitudes, processes, and products as they relate to the needs of the layman. Because of this lack, varied claims are made as to the nature of the scientific method, as to the importance of certain attitudes, as to the relative significance in education of techniques, concepts, hypotheses, principles, and facts. The PSSC course is based on the assumption that the ability to conduct inquiries in physics is the most important contribution that physics can make to the high school student and that the second most important is the ability to explain and predict physical phenomena by using basic concepts and generalizations. This is a very different emphasis on objectives from the majority of textbooks. The analysis of the possible contribution of science to the behavioral repertoire of the layman should be done by competent scientists, and scholars in history, philosophy, and sociology of science, and by psychologists who can formulate models of the behavior involved in these several aspects of the scientific enterprise.

Another phase of needed research in the area of objectives deals with the philosophy and psychology of man toward which science education can be directed. Can man be conceived as an active organism, raising his own questions, building his own knowledge, solving his own problems? Or is man better conceived as one who learns what the questions are, what the facts and principles are, and what the answers to questions are? Perhaps, a better way to formulate this kind of research is to raise the question: To what extent is man a discoverer and creator and to what extent a follower and an acceptor of doctrine? Or perhaps the question is: Which men can be educated as followers and acceptors? Basic issues on the nature of objectives in science education are involved in this conception of the possibilities inherent in man. We need studies by psychologists, historians, and philosophers that give us a more comprehensive picture of the alternatives. Without this kind of research, we assume one possibility in developing courses using learning by discovery and assume a different possibility in man when we build a course in which the basic learning theory is conditioning.

Another kind of research needed in the area of objectives deals with the level of generality or specificity required for an objective to be both efficient and attainable. All learning aims at generalization; what the child learns in school we expect him to use in life outside the school. But the question of the extent to which he perceives the general meaning and applicability of what he has learned is still one that is answered very differently in different science courses. In some, the objectives are at a very specific level such as knowing each of several hundred facts while others are at a higher level of generalization, such as, to explain a phenomenon which is new to the student by using concepts and principles familiar to him. As one examines current courses in science he finds very wide differences ranging from those with lists of several hundred objectives to those with less than twenty. Both psychologists and philosophers could make constructive contributions in research on this problem of the possible and desirable level of generality for objectives.

There are other kinds of significant studies to conduct in the areas of objectives but these three should serve to illustrate the need and the possibilities. Research in this area can furnish knowledge and insights that will improve our efforts to formulate significant objectives to guide the development and conduct of programs of science education.

Research on the Teaching-Learning Process

This has always been an area that has attracted researchers in science education. But the investigations in this field have not made adequate use of the concepts and models which are emerging from the work of scholars in related fields. Furthermore, some of the current studies appear to attack learning in science without concepts to guide them. Some of the promising possibilities for new investigations will be briefly illustrated.

Studies of Pace, Stern, and others, initially conducted on college campuses have shown that the intellectual and affective environment of the school influence measurably the direction and extent of student efforts to learn. The atmosphere varies among schools, some impressing their students with the expectation that questions will be raised, problem areas will be seriously examined, and that intellectual discussions are significant and enjoyable. Others may give students the impression that athletics, or social life, or individual aggrandizement are the matters to be given major attention. Still others create for the students a sense of being cold; students are tolerated, but not wanted and the desirable thing is to get away from the school as easily and quickly as possible.

These investigations indicate that students not only sense the expectations of the school's environment, but are also influenced by it in the way they spend their time, what they try to do, and how they feel about their achievements. Hence, the educational effectiveness of the school is partly dependent upon the climate created.

Research is needed on the nature of the school climate which influences students of science and how their study and achievements are affected. Investigations are also needed on the way in which particular climates are created. The results of this work can provide useful bases for improving learning in science through the development of a school climate more congenial to it.

As another illustration, the work of social psychologists clearly demonstrates the powerful influences of peer groups upon the direction and extent of school learning. What one's friends value, how one's friends spend their time, how they attack their work, what they expect to achieve, and what they find rewarding are significant factors in one's own attitudes and practices. However, although for many years we have known in general the importance of peer groups, their particular influences in learning in science have not been fully studied. Few investigations have been undertaken to learn how peer groups form, or can be created, that will encourage, guide, and reward desired learning in science. Research of this kind would give a further basis for improving particular programs of science education.

As a third illustration, personality psychologists have developed the concept of identification as an important process in the development of the human individual. As we grow up, we find some attractive persons in our environment whom we seek to emulate. We develop attitudes, beliefs, and habits like the perceptions we have of these attractive persons. We know very little about the process of identification in science education. What kinds of teachers of science attract students who seek to emulate them? Do these teachers provide a clear example of significant attitudes, beliefs, and practices helpful in learning? What people other than teachers attract students? How well do they exemplify desirable aspects of science education? Research on these questions is likely to furnish added knowledge and insights helpful in improving learning in science.

The three kinds of research suggested thus far are focused on factors other than those involved directly in teaching in the classroom and laboratory. The most common model used to guide planning and conduct of teaching itself is one of the teacher having in mind a certain kind of behavior for students to learn. He provides opportunities for the students to practice this behavior, stimulates them to try, guides their efforts, and rewards successful performance. Although this is a commonly accepted model, we have little evidence to indicate how far this model is actually followed by teachers of science and, if it is not followed, what are the difficulties? Investigations are needed of the conceptions teachers actually have of the objectives they are trying to attain in connection with particular units, what behavior they are trying to get students to carry on, how they try to stimulate and guide the behavior, and how successes are rewarded. At the same time, information should be obtained from the students of these teachers regarding their perceptions of the behavior they are trying to learn, what they are expected to do, and what they are actually doing. Accompanying the data from teachers and students there should be reports of observations made in classroom, laboratory, and study room regarding the actual behavior of teachers and students. Research of this sort should throw much light upon the problems to be solved in improving the teaching of science. Such investigations carried on in other fields have shown that many teachers have conceptions of the objectives and the learning experiences that differ from those outlined in the courses of study. Often, too, the behavior actually carried on in classroom and laboratory is not that which the teacher wants the students to learn. Difficulties in learning may often represent problems of effective teacher education rather than simply problems of curriculum and instructional materials.

These four kinds of research on the learning process are sufficient to suggest the possibilities in this area. There are, of course, several other kinds of research needed.

Research on the Organization of Learning Experiences

The learning of science is not the acquisition of a great many specific and unrelated behaviors, each of which can be acquired in a lesson or two. The development of adequate understanding and use of the problem, the means of inquiry, and the concepts and generalizations of science requires months and years to achieve. The learning of today must build on the learning of yesterday and the learning of tomorrow must build on the learning of today. Furthermore, to understand science is to understand and make appropriate adaptations to the similarities and differences between science and other ways of knowing and dealing with the world. We are, in science education, concerned with the sequential development of learning and with integration, the relationships between science and other fields. To bring about effective sequence and integration is the problem we seek to solve through the ways by which learning experiences are organized. Thus far, however, our efforts at organization have not been guided by the results of research because there have been very few investigations in this area.

Studies by scientists and philosophers of science are needed that seek to identify the elements of a scientific discipline which can serve as the enduring cores around which new learning can be built. Researchers interested in learning should investigate the alternative principles on which integration can be attempted. Various principles have been proposed. For example, as principles of sequence, some courses move from the phenomena familiar to the child to those that he has not seen before; some begin with structural aspects of biological organisms, then move to functions; some begin with abstract analysis, then move to applications; but other courses follow these principles in reverse. What can we find out from experiments in learning that will help to establish better sequences?

Similarly, the principles followed in organization to achieve integration have not been well-tested. Some courses emphasize the similarity in scientific method and all modes of inquiry; some choose certain topics and examine them in terms of several disicplines, while others outline the differences in problems, purposes, modes of inquiry, and results among the various subjects students are taking. We need more experimental work on principles of integration that do justic to each discipline and at the same time, help the student to deal with the world using appropriate tools, and not keeping each subject in isolated compartments.

Research in the Outcomes of Science Education

The wide use of achievement testing provides a large amount of data on some of the outcomes of science education. But the limitations of current tests and the relatively short time spans involved in studies of achievement have provided us with a less helpful knowledge than we need to guide our work. The recall of facts, the solution of stereotyped problems involving mathematical calculations, and the recognition of applications of science generalizations are most commonly tested. Increasingly, tests of applications of principles, interpretations of data, and procedures for testing hypotheses are being used. Unfortunately, test construction has been heavily dominated by theories and practices developed from attempts to identify and measure individual differences. Items at the 50 per cent level of difficulty are most efficient in discrimination. We rarely assess what all, or almost all the class learns, or what the most advanced learn. Research is needed to develop better measuring instruments which appraise all the important objectives in science education, which apply to the entire range of students and which provide measures precise enough to test the hypotheses we formulate about the effectiveness of curricula and of teaching-learning processes.

We also need studies of the outcomes of sequences of learning in science and the extent to which these changes in behavior persist over long periods of time. Today, the realization that scientific knowledge is being acquired at a rapid rate has given emphasis to the objective of developing on the part of the student continued independent learning rather achieving an understanding of science that will last him throughout his lifetime. But we have had little experience in trying to teach students so that they will have long-term interests in continued learning, be able to study under the conditions they will face after the school years, and have developed supporting habits. For this reason, we need research on the persistence of independent learning after several years.

These three kinds of research in the area of outcomes of science education serve as examples of the sorts of investigations which can make significant contributions to improvement of science education. Other illustrations will come readily to mind.

Research on the Student's Development

Since 1925, a great deal of research has been conducted on the development of children and youth. Some of these studies have provided useful concepts and generalizations for planning science curricula; but most of the work has focused on the general developmental processes and problems. We need investigations that examine development in relation to science education. Three examples of the kinds of research needed should suggest the possibilities in this area.

We need longitudinal developmental studies of the decisions, both conscious and unconscious, made by young people that result in attitudes toward science, in interests in studying science, in taking courses in science, and in conducting out-of-class activities involving science. Operations research and operations analysis as carried on in engineering and in industrial science provide a partial model of the kinds of investigations that can be made by treating individual children in this research as raw materials are treated in operations analysis; by charting the major events, and choices made, development can be followed through childhood and adolescence to identify resulting products, that is the outcomes of science education, or lack of it. The studies should be summarized separately for boys and girls, for different socio-economic levels and for rural, urban, and suburban children. This should throw further light on the ways in which childhood curiosity about the environment is encouraged or repressed, how it is channeled into educational experiences, and the events and forces which influence attitudes, practices, and educational choices. We know that more boys choose science courses than girls, and that attitudes toward and interest in science seem to fluctuate from childhood to maturity, but we know very little about the factors involved, how they operate, and at what times in the life cycle choices are made that relate to science education. Curriculum planning and educational guidance would both benefit from this kind of research.

A second kind is related to the first. We need studies by psychologists, sociologists, and anthropologists on the influence of the family on the child's development of attitudes toward and beliefs about science. There is some evidence to support the generalization that in the home girls learn to think of science as a subjeft for boys, but we have little knowledge of the interaction in the family which helps to shape these beliefs. Since the family structure is different in different ethnic groups and in different socio-economic classes, investigations of this kind should analyze different groups separately. Some success is being achieved in teaching reading to disadvantaged children by taking into account the language aspects and liabilities of different kinds of homes. Similar improvements might result if we knew more of the dynamics relating to science.

A third kind of needed research on students is that of the differential development of cognitive processes among children and youth. By age six, there are wide differences among children in the extent to which they attack problems they encounter by making various random efforts or by trying to think out what might be done before taking the steps. These differences are likely to increase with age. Science education is largely devoted to cognitive processes where abstract concepts serve to guide perception and action. Under what conditions do cognitive processes develop? What factors impede? How can science inquiries be constructed so as to build on a limited cognitive level and at the same time, help to raise the level? These studies require work with individual children and should include both investigations of present development and also experiments aimed at facilitating cognitive processes.

These three kinds of research are suggested again only as illustrations. They do not exhaust the possibilities for research on student development that can contribute to the improvement of science education.

The Other Research Areas

The remaining six of the eleven areas listed above will not be elaborated here. Studies on the development of science teachers are needed to gain a better understanding of who goes into this field of work, what factors influence his choice, and the dynamics that help to shape the teaching career. Results of such research can help in recruiting, educating, and rewarding science teachers. Areas seven, eight, nine, and ten in the list above are areas relating to the curriculum for educating science teachers which parallel areas one, two, three, and four relating to the curriculum in science education. Similar kinds of investigations are needed for the development of both curricula. I shall not attempt to suggest kinds of research needed on the processes of change in programs of science education since Professor David Clark has given much more attention to this area and will make a presentation later this week.

The listing of the eleven areas and the illustrative elaboration of five of them is intended to indicate that a comprehensive map of the terrain of science education can be constructed by selecting parts of the total map to be areas of intensive research. Research of this sort should indicate more clearly what concepts are centrally important in understanding science education. The results of such research should help us in building models which suggest the dynamics of the processes in our field and in this way, aid us in constructing effective plans for improving science education.

Resources in Improving Research

The most important resource required is obvious to us all, highly competent research people who are deeply interested in, and able to devote at least a third of their energy to research in science education. Closely following in importance is the involvement of graduate students of high quality who can devote at least half of their time to this research. A third important resource is the involvement of excellent natural scientists, behavioral scientists, and scholars from philosophy and history in investigations related to science education. The research worker in science education is in the field as a carreer. Colleagues from the other disciplines cannot be expected to make a career in research relating to science education but each of them may be willing to work for several years on an interesting project that utilizes his special competence. They should be strongly encouraged to do so. They have important contributions to make.

Other resources required include a good library where most of the reports of research in the sciences, the behavioral sciences and in education can be obtained; cooperative arrangements for studies in schools and colleges in the vicinity; and facilities for preparing instructional materials, designing simple laboratory apparatus, and reviewing films and tapes.

A very important resource is a place where children may be taught individually or in small groups and where learning activities can be observed and recorded. One of the great handicaps to imaginative developments in education is the habit of thinking of teaching and learning as a classroom activity in which a teacher and 15 to 40 pupils will be engaged at the same time. Tradition has given the schools classrooms and class teaching, but children can learn in many other situations. We need to devise learning situations in which only one or a few children are involved in order to understand the processes more clearly and fully. Then, we may be able to design effective teaching situations of other types than the typical classroom. Hence, the science education center needs places for experimental teaching and learning which are appropriate for individual work, for a few students, and for larger numbers.

Another important resource is the opportunity for communicating with other science education centers so that each may learn from the others. Conferences like this in which major problems are discussed, or plans are developed jointly, or reports are given of significant work under way are helpful. A deeper level of communication is possible if provision is made in a center for a visiting professor from another center and one or two post-doctoral fellowships are available for graduates who have previously worked in other centers.

This discussion of necessary resources assumes that the university is thoroughly committed to the support and encouragement of a Center for Research in Science Education. Commitments must be made of faculty time, of graduate student support, of facilities, and of research assistance.

For research in science education to make the contribution needed, it must be a recognized and supported part of the university. The relatively low quality of much of the research done in the past has been due to the fact that studies have largely been carried on by graduate students with little time to devote to these efforts. The experience of other fields has shown that research can be improved when excellent scholars devote major time to problems that are intellectually important.

ISSUES AND PROBLEMS IN SCIENCE EDUCATION

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THE SITUATION

Science and technology, during the past decades, have played an important role in the evolution of Western Culture. Our rapidly changing society has been stimulated by new advances and developments in science, thereby, placing new and greater demands on the entire educational system -- particularly on the science and mathematics programs in the school. The unparalleled expansion of scientific knowledge has placed new responsibilities on classroom teachers and has brought about a changed emphasis on elementary, secondary, and college science. As a result, the objectives of science education have been examined and evaluated; local, state, and national groups have participated in the selection and organization of course content, and the methods and techniques of instruction have been modified to meet new program demands.

During the past decade science, as a part of general education, has become an important part of elementary school programs, has expanded in scope in the secondary school, and has become an important area of study in most college degree programs. This new emphasis on science has raised many problems and issues which need to be resolved if further progress is to be made in science teaching.

The many factors influencing science education today, including increases in school population, expansion of scientific knowledge, the great need for a scientifically literate society, and the need for scientists and engineers, the changes in the processes and goals of science, new curricular materials, and many others, serve as a reminder of the extreme importance of maximum research efforts in seeking solutions to the many problems raised. Carefully planned and executed research programs would provide the necessary basis for further improvement in science education. Evidence gained through research is needed for critical analysis and evaluation of curriculum innovation and experimentation to determine their contribution in the general improvement of science teaching. Changes in the objectives, content, and methods of science programs do not insure improvement in the courses or in the instruction.

Science educators have been concerned about research in science education since the turn of the century. There is general agreement that research activity must increase in quantity as well as in quality. There is need for a group, possibly the participants at this conference, not only to identify and study the issues and problems needing to be researched, but to develop structures and/or models, and to plan strategies for their resolution.

Local Science education centers and national groups, such as the National Association of Research in Science Teaching, and the U. S. Office of Education have, during recent years, been instrumental in keeping the problems of science education in some degree of focus. It is imperative that cooperative programs for action research be developed and implemented in the immediate future.

It is the purpose of this paper to present a suggested list of the major issues in science education along with related problem areas that have been identified by science educators, psychologists, classroom teachers, and laymen over a period of years. It is not intended that this list be all inclusive, or that it represents the only important ones. Rather, it is a list (not in order of importance) representing a portion of the more obvious issues and related problem areas which, because of the nature of their complexity, demand the best thought and action of science educators.

ISSUES IN SCIENCE EDUCATION

There are many perplexing situations or areas in science education which cannot be reduced to simple questions for easy answers, but which are by their nature very complex. In final analysis, their complexity may make them natural topics or points for debate. A review of the current literature, committee reports, research studies, and discussions with science educators reveal the following issues needing further research. In the presentation that follows, the issue will be identified and described -- suggestions, models, and strategies for dealing with the issue would evolve from small group discussions.

For convenience the issues and related problems are grouped into four major areas.

1. Issues Related to the Purposes of Science Education.
2. Issues Related to the Selection and Organization of Content.
3. Issues Related to Methods of Instruction.
4. Issues Related to Teacher Education.

Issues Related to the Purposes of Science Education

The purposes of science education reveal, in a general way, the accepted value systems of a society and identify some of the characteristic cognitive skills needed by each member of that society. There is universal agreement that science teaching must result in the development of scientifically literate citizens. Attempts have been made to identify the characteristics of such persons and include: mastery of knowledge, accuracy of observation, qualities of curiosity, open-mindedness, and certain feelings and values essential to living in a modern-day society. Today goals of science education are many and they are divergent. Many kinds of types of science curricula have been designed and developed in an attempt to achieve the important purposes of the area. There appears to be some danger that as a result of the new emphasis on science and new curriculum materials certain science objectives will become dominant over or inhibit the development of other important goals. Considerable

b) The fields of scientific competence and scientific literacy need to be more adequately defined, delineated, and analyzed.
c) A basic need exists to develop a firm concept of science as a process.
d) Realistic purposes for a science program K-16 should be determined.

Issue 2.

Shall the basic purpose of secondary school science be the general education of all students or the special education of a limited group?

During the past ten years attempts have been made to change the emphasis in science education to include as a central part of the program experiments which enable the pupil to see, observe, and begin to cope with some of the basic problems and perplexities of science. This has resulted in science programs that are in many ways esoteric to pupils and teachers alike. Not all teachers or pupils are able to understand the structure of science, to use inquiry and discovery approaches, or to comprehend the processes used by scientists in solving problems.

Some individuals believe that the only concern in science education should be the maximum development of the academically talented pupil. They consider it a waste of time, energy, and talent to educate the others. Some of the new science programs reflect this point of view. Not only have curriculum makers concentrated their efforts on the average and above average student, they are reluctant, in some cases, to provide for the other segment of the school population.

Others believe that science, in some form, is important for all students K-16; it is a part of general education. They question whether science as a mode of inquiry with emphasis on theory and major concepts is the best kind of science for all. Time spent on developing concepts and methods of inquiry reduces the time that could be spent on technological aspects or applications of science.

Related Problem Areas:

a) We are faced with inadequate knowledge as to what concepts can be introduced and taught at a specific level.
b) A science program should be made available to all students -- low, average, and high ability groups.
c) The rationale of the role of science in the totality of the school program must be based on research findings.

Issues Related to the Selection and Organization of Content

Two elements of extreme importance in the selection and organization of the science curriculum are, the changes in science and in the social

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Issues Related to the Selection and Organization of Content

Two elements of extreme importance in the selection and organization of the science curriculum are, the changes in science and in the social scene. Science has been defined as a systematic and integrated body of knowledge forming a logical structure. It involves processes whereby the facts, concepts, and principles are under constant study and evaluation. Continuous changes in science complicate the work of curriculum makers. Curriculum content must be selected which not only draws from modern scientific knowledge but which is useful in helping the student develop and understand the basic structure of science.

Conventional science courses have been criticized for being too repetitive, largely descriptive, inadequately articulated, and containing too much applied science and technology. In general, the courses were fragmentary, based on current factural information, and lacking in integration within the science areas and with other subject areas. Recent attempts at curriculum design and development utilize the major conceptual schemes or the big ideas of science that have been identified by several curriculum groups. These schemes provide the skeleton upon which to build an integrated curriculum K-12. Some critics suggest that the core of this science program should be the basic scientific ideas of the age. Others insist that science curriculum makers should study the scientist at work, analyze the procedures and processes used, and make these central in the science program.

Much work remains to be done before satisfactory curriculum practices become a reality. There is need for developing practical criteria to use in selecting and organizing content for it is no easy task to transmit to the next generation the basic intellectual achievements in science and at the same time develop an understanding of the processes by which these achievements were made. What to teach and how much has been a major problem of each generation.

Issue 3.

Shall the social impact of science and technology be a central function of the curriculum in secondary school science or shall it remain an individual function?

The place and function of science education in our society is determined by, and dependent upon, science and technology. In general, changes in society act more slowly on producing changes in the science curriculum than do changes in science.

Many members of our social culture believe that greater attention must be given in curriculum design and development to the impact of science on social conditions, economic development, and on man's thinking. Young people must be made alert and prepared for change and progress if they are to meet and solve the problems of a changing society. A science curriculum is needed that is organized around major social problems, conservation of natural resources, food supply, health and safety, and population control. They believe that science education must play an important role in preparing young people to live in a world whose problems are yet unknown using scientific knowledge yet undiscovered.

Other critics believe that it is not the function of science education to reveal the impact of science and technology on society. This should be left to other areas of the curriculum. The central function of a science curriculum in their opinion, is to provide opportunities for students to grasp the structure of a subject area and to guide them into its discovery. To this group of critics social applications of science are, in final analysis, not real science; only the technical use of science.

Related Problem Areas:

a) The place and function of science education in a democratic culture is dependent upon science and technology.
b) Change should be made in the school science program to provide for the impact of scientific and technological advances.

Issue 4.

Shall there be efforts toward a national curriculum in science or shall local, state or regional curricula prevail?

Much has been written during the past few years regarding the advisability of having regional and/or national commissions responsible for determining the science understandings, the values, and the competencies needed by all individuals to live in a modern society. Essentially, they would design and develop all science curriculum materials. Science educators, teachers and school administrators have expressed concern over this approach to curriculum development.

Proponents for a national curriculum claim that the explosion of knowledge in the basic sciences makes this approach to the science curriculum a necessity. A national commission could identify the major concepts or understandings needed by all students. Such a curriculum would be uniform, easily understood and implemented. It would make possible the standardization of facilities and equipment, and would lead to the development of national standards for teacher education and certification. While many of these arguments may solve some problems in science education, they would raise many new ones.

Opponents to the development of a national curriculum claim that such a curriculum would not meet the needs of students of all ability levels; it would limit or destroy local and state curriculum innovation and experimentation; it would place the control of science education in the hands of a special group, and would not solve the critical issues in science education. They are convinced that individual teachers, representing a wide range of interest, ability, and background preparation would never subscribe to such a proposal.

Educators, science educators, and teachers have been alarmed during recent months by action at the national level for the development of comprehensive examinations in the various disciplines taught in the secondary school. Many oppose this movement believing that it would eventually lead to a national curriculum and force teachers to teach for the examination rather than for the accepted objectives of education. Others believe that a real danger exists when a special group or groups of individuals gain control of any segment of the educational program. Tests developed by a special group or groups would enjoy a special authoritative status, thereby, forcing administrators and teachers to accept them to maintain educational status.

Related Problem Areas:

a) We need new systems for the organization of scientific knowledge.
b) National commissions or councils would, in due time, control curriculum development in science education.
c) Curriculum design and development cannot be done at the local level because of the lack of qualified personnel and limited financial resources.

Issue 5.

Shall the plan of the secondary school program continue to be based on the design of first year college science courses or shall the plan be based on the needs of students?

The relationship that should exist between secondary school science courses and college courses has plagued curriculum writers for many years. Until comparatively recent, tradition played a major role in content selection and organization. However, recent developments in science, both in knowledge and theory, makes curriculum development along traditional lines questionable.

Some scientists and teachers believe that the major purpose of secondary school science is to prepare young people for college. The more nearly the high school course is like the college course, the better it is. This is especially true of science teachers assigned accelerated classes or classes in advanced placement.

There appears to be no real agreement as to the major role the secondary school science program should play in preparing students -- whether preparation should be for general education, for a vocation, or for a future profession. Critics have raised questions regarding the desirability of highly specialized science courses for a select few students rather than science courses for all students K-12. Others believe that the secondary school science program should be planned irrespective of college courses, that it should be integrated, and that it should have a coherent structure and continuity.

Related Problem Areas:

a) A rationally conceived and designed science program in all

levels of instruction through college is a problem of first magnitude.
b) Criteria should be developed to be used in the selection and organization of learning experiences.
c) Identification of basic conceptual schemes in science is essential for progressive curriculum development.

Issue 6.

Shall the science curriculum be textbook-centered or experience-centered?

Recent curricular developments in science education emphasize the importance of discovery, investigation, and/or inquiry in teaching modern science. That a trend towards more experience-centered curriculum exists, in the minds of curriculum makers, is quite evident. However, regardless of the efforts in curriculum revision to restate objectives and to modernize content and method, much of the science taught in schools today is still textbook-centered. Evidence is needed to show that the experience-centered approach to science teaching contributes in a greater degree to the realization of the accepted purposes of teaching and in the development of understanding of the structure of science and its processes.

Critics of the experience-centered curriculum say that new curriculum developments have resulted in little more than substituting one textbook for another without appreciable gain in either objectives or content. Some believe that the objectives of the experience-centered curriculum are unrealistic, unattainable, and not in keeping with the true spirit of science. To this group the textbook is the most important tool in science teaching -- it defines the field, capsulates the content, and provides the same exposure for each student.

Educators supporting the experience-centered curriculum believe that it is the only approach that will enable the student to attain the real objectives of science education -- interest, attitudes, appreciation, and problem-solving abilities. The textbook limits science at a time when the student should be free to explore, investigate and ask questions about nature. Through science experiences the student can be taught intelligent, responsible citizenship. This approach provides for permanence of learning by developing intelligent self-direction in students.

Related Problem Areas:

a) A science curriculum may be based on the social unity of science, its fundamental and pervasive ideas, or on the applications of science to daily life.
b) First hand experiences in science (discovery) are essential to understanding science concepts and principles and in comprehending the processes of science.
c) Textbooks, properly written, provide a well articulated science program from grade one through twelve.

d) Elementary school science taught departmentally by a science specialist is preferred to science taught in a self-contained classroom.

Issues Related to the Methods of Instruction

The success of a curriculum depends upon the method of instruction used. Recent curriculum projects in science education demand teaching procedures that are consistent with the goals and concepts identified. Emphasis on developing an understanding of the structure of science has resulted in the development of methods of teaching inquiry, investigation, and/or discovery. Modern methods of teaching must include all aspects of instruction, such as: the purpose to be achieved; the structure of science and its conceptual schemes; the motives and potential of the learner; the background and philosophy of the teacher; and the sequential, integrated organization of the content.

Regardless of efforts to improve instruction through curriculum projects, there is still much concern about the methods used in teaching science. There is little evidence to reveal how successful or unsuccessful suggested methods of instruction have been. It is reasonable to assume from observations that what teaching procedures have been planned for a classroom and what actually happens in a classroom may differ considerably.

Issue 7.

Shall science instruction be predicated upon large group procedures or upon individual learning activities?

Increased enrollments in science, lack of classroom space and facilities have forced science teachers to consider and/or develop new instructional procedures. Team teaching, large group lectures, flexible scheduling, programmed learning materials, television, and many other techniques and/or devices have been developed. New instructional materials and devices appear on the market at a faster rate than they can be tested and evaluated by classroom teachers.

Some teachers and administrators believe that science can be taught just as effectively using large or small group procedures. Efforts have been made, particularly at the college level, to eliminate the laboratory part of science instruction by substituting closed circuit television laboratory demonstrations. Reliable evidence is lacking to support or reject the use of these teaching procedures. Regardless of evidence or lack of evidence, some administrators believe science teachers will be forced to make maximum use of many new techniques and devices in science instruction.

Others believe that recent curriculum projects place great emphasis on individual instruction for efficient and effective instruction in science. While some new devices may assist in improving instruction they should not become the only method used. They believe that to achieve the goals of understanding the structure of science and its processes, science teaching must include experience in individual learning activities.

Much research needs to be done to produce evidence as to the contribution of the various methods of instruction in the teaching-learning process.

Related Problem Areas:

a) We are faced with an inadequate knowledge of the psychology of learning.
b) A basic need exists to develop a firm concept of science as a process.
c) A need for more effective methods and/or techniques for teaching science is evident.
d) Known evidence regarding teaching procedures should be more widely demonstrated and disseminated.

Issue 8.

Should the laboratory be central in the teaching of science or should it play a secondary role?

Many science teachers maintain that the science laboratory provides the only opportunity for students to relate concepts and theories, observations and experiments, data and conclusions.

They believe that the laboratory provides a place where problem-sovling activities can be carried on, and where problems and be identified and solved through the acquisition of adequate data. The laboratory plays a major role in current curriculum projects through use of demonstrations, experiments and investigations. Teachers using these materials contend that the laboratory plays a major role in identifying and developing the correct modes of scientific thought leading to a true understanding of the processes of science.

Other teachers believe that the importance of the laboratory has been exaggerated, that it does not contribute to learning to the degree claimed. To this group the net gain in learning is not worth the teacher and student time necessary to plan and implement a laboratory program. The lack of evaluative instruments to measure the students' ability to observe, discriminate, classify or make predictions leads this group of teachers to question the real contribution made by laboratory procedures.

There is general agreement, on the part of many teachers, that to understand the scientific enterprise is to understand the processes and/or methods by which problems are solved. They contend that greater attention to the processes or methods rather than final answers or conclusions should result in better understanding of the structure of science. However, until some reliable evidence is obtained supporting the role of the laboratory in science teaching, it will be difficult to make satisfactory progress in science curriculum improvement programs.

Related Problem Areas:

a) Investigatory laboratory experiences are the best kind of experiences for all ability levels.
b) Laboratory experiences appropriate for each grade level should be identified.
c) Criteria are needed to evaluate the relative effectiveness of laboratory experiences in the elementary and secondary schools.

Issues Related to the Preparation of Teachers

Maintaining an adequate supply of competent science teachers has been a major problem in science education for many years -- increasing in magnitude and importance during the past decade. There is general agreement that a teacher must know his subject, understand the diverse route by which a student can understand the subject, and know the psychological processes followed by a student in following a particular route. Some critics believe that this kind of teacher can only be prepared in a liberal arts college -- an institution that has as its core the classical discipline of learning. While such schools would provide mastery of subject matter, it is doubtful if they would understand or utilize the diverse ways to mastery and the psychological principle involved in mastery. Others contend that a balance is needed between academic and professional preparation. There is little evidence as to what makes a science teacher good or the kind of program that makes him most effective. Available evidence points to the need for institutions preparing science teachers to promote experimentation and innovation in developing future programs. As a result of this conflict, the following issues should be considered for active research programs.

Issue 9.

Shall the academic program for the preparation of science teachers be unique in its design or shall it be the same as that for prospective graduate students in science?

Science teachers of the future, regardless of type of undergraduate programs, will be no better than the quality of individuals selected for, and retained in, the teacher preparatory programs. Some critics hold that it is the individual and not the program that makes a quality teacher. Teachers differ as do students, ranging from highly effective individuals in the classroom to those that interfere with the normal emotional and intellectual growth of young people.

There is some general agreement that science teachers should have both breadth and depth of preparation in the basic sciences. Some critics of teacher education programs believe that it is the quality of the hours taken in a given science rather than the number of hours or credits earned that is responsible for developing effective teachers. Science teachers should also have experiences in the arts, history, literature, and philosophy.

Other critics of current teacher education programs believe that science teachers should be steeped in subject matter for its own sake. The real emphasis, in their opinion, must be in the basic science disciplines obtained through a liberal arts program which would be essentially the same as that of a prospective graduate student in science. Such courses, properly taught, would all but remove the need for courses in pedagogy. Opponents to this position believe that the traditional liberal arts colleges do not understand or apply the basic principles of learning that lead to mastery of a subject-matter area.

There is little evidence to support the various positions taken by critics of teacher education -- we are still perplexed by the problem -- What makes a science teacher good?

Related Problem Areas:

a) We need a more fundamental delineation of the behavioral competence of science teachers.
b) The program for preparing science teachers must have an adequate design, rationally conceived and justified on the basis of research findings.
c) Changes are needed in existing college courses and/or new courses are needed in science teacher preparation programs.
d) There is need for prospective science teachers to be involved in experimental scientific research programs.

Issue 10.

Shall the preparation of science teachers include a knowledge of the psychology of learning and human behavior or be limited to a liberal education with appropriate preparation in science?

For decades the science teacher has assumed the role of transmitting knowledge or a transmitter of our scientific and cultural heritage. New curriculum programs have, in theory, but not necessarily in practice, redirected the teacher's role. That the new curriculum projects have produced changes in education in the elementary and secondary schools is quite evident. What do these changes mean for science teacher education in colleges and universities? Unfortunately new curriculum developments in science did not occur simultaneously with new program developments in teacher education. We find ourselves in a peculiar paradoxical situation -- having started at one point in improving instruction, when it might have been better to have started in another.

In science teacher education two opposing points of view are evident. The old fight between substance (subject matter) versus method still prevails. One group believes that mastery of subject matter is the primary goal of the undergraduate program for teachers. That majoring in a particular science area is essential for a teacher to be effective in the classroom. The science teacher must be able to work, talk, and act like a scientist -- to know his subject is to be able to teach it well.

Others believe that science teachers must have experience in the basic liberal arts program, with breadth and depth in science sufficient to understand its structure and be able to guide students into its discovery. This implies a thorough understanding of the teaching-learning processes -- a viable learning theory essential for the successful use of materials in the classroom.

Another group suggests that a fifth year be added to the program -- a year of apprenticeship in which the prospective tacher works with curriculum researchers in the innovation and experimentation with teaching-learning materials under classroom conditions. It is believed that research of this kind is essential if the teacher is to lead students in inquiry and/or discovery.

Related Problem Areas:

a) The profession must achieve means of developing life-long academic and professional growth in science teachers beginning at the time that the individual has made a professional commitment.
b) Science education must find a means of self-regulation and self-discipline as an aspect of professional integrity.

Issue 11.

Shall the licensing of science teachers be a function of the state or of the institutions preparing teachers?

Traditionally state departments of education have assumed three major functions: (1) regulatory, (2) operational, and (3) leadership. State controls over who should teach, and in what area, has been historically of considerable importance. However, the situation today is quite different. Many critics believe that the rapid changes in science, in psychology, in curriculum development and the slowness of state departments of education to adjust to change make this arrangement entirely unsatisfactory. Specific subject matter requirements, in major and minor teaching areas in most states, are not adequate to permit teachers to cope successfully with modern curriculum materials. As a result, teachers with inadequate preparation in the subjects they teach are fully licensed to teach by state standards.

Many believe that the state, and only the state, is in a position to determine and enforce minimum requirements for teacher certification. The many kinds of institutions having programs of teacher education and the great differences in these programs make it impossible to maintain a degree of uniformity without state control.

Other critics maintain that the college or university is in a much better position to determine the amount and kind of teacher preparation needed to teach in a specific area. They believe that each institution should be given freedom to utilize the unique characteristics of their course offerings, based on predetermined principles of certification. Colleges and universities can modify and/or change programs rather quickly to modify existing courses or introduce new ones when the situation demands. The elimination of teaching minors would provide for greater flexibility in the teacher preparation programs, thereby, providing for greater breadth and depth of preparation.

Related Problem Areas:

a) Nationally recognized standards should be used in evaluating teacher education programs.
b) There is need for greater reciprocity between states on matters of teacher certification.
c) Institutions, professional organizations, and school officials should have major responsibility in determining adequate teacher preparation programs.

THE CENTER FOR SCIENCE EDUCATION IN CHANGING EDUCATIONAL PRACTICE

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It is the purpose of this paper to consider the role of Centers for Science Education, regardless of their specific functions or pattern of organization, in contributing to change in educational practice. To accomplish this purpose it is desirable to review some of the changes that have occurred in science education in the past, some of those that are occurring at the present time, and to speculate on the potential for the future. It should be recognized as a prelude to this discussion that Centers for Science Education, as such, are relatively new in all except a few institutions that have pioneered in the development of such organizational efforts and programs. Thus, Centers for Science Education may or may not have been involved in the change. On the other hand, a survey of some activities that have resulted in change can be useful in planning the role of such centers for the future.

In what areas can we expect change to be effective? Fundamentally, these areas are in: (1) the preparation of prospective science teachers; (2) the development of programs and materials to aid teachers in service; and (3) research of educational problems that need to parallel, but not necessarily precede the development of new curriculum materials that have promise of improving science instruction. Following activities in all of these areas, evaluation must be a part of the total effort. It should also be emphasized strongly at this point that the success of all of these efforts is dependent on a high degree of team effort -- in the preparation of prospective science teachers and in the development of curriculum materials, team effort with active professional scientists in the respective fields of science and in research and evaluation, team effort with professional psychologists specializing in evaluation and research. Such team efforts, however, should not minimize the responsibility of Centers for Science Education to participate as a full partner in the programs.

If science education is to be recognized as a discrete discipline (and there are those who think it should not be so recognized) then it must be neither psuedo-science nor psuedo-psychology -- it is more specifically curriculum and instruction (of a specific kind, of course). Science education as a discipline uses science content as a raw material and psychology as a tool for its specialized efforts, and thus involves cooperation with both professional scientists and psychologists. However, it is impractical to expect the science educator to be both a professional scientists and professional psychologist as some of our colleagues imply from time to time. There is an important place for the science educator to carve for himself among the areas of science, psychology and education. The Center for Science Education can provide the organizational framework to accomplish this possibility.

But now let us survey briefly some of the changes or lack of changes in science education over the past several decades. Hurd has noted that during the past 70 years more than 100 national level committees have been set up to study education in the sciences to make recommendations for improvement.[1] The problems studied and the recommendations made have been essentially the same during this period. However, the changes effected, at least up to the current major curriculum developments at the national level, for the most part have been small.

There have been some changes in science textbooks during this period. This situation has been summarized in the Biological Sciences Curriculum Study Teachers Handbook.[2]

> In the first phase of the history of the American science textbook, extending from about 1890 to about 1929, the basic model for the conventional textbook was laid down. This basic model was determined by two factors: the state of the science at the time and the supposed goals of the high school student . . .
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> In the second phase of its history, from about 1929 to 1957, the earlier textbook was extensively but not fundamentally modified. The modifications were brought about by a new determining factor -- concern for the increasingly diverse abilities, interests, background, and intentions of high school students. Unfortunately, these modifications were often achieved at the expense of the best feature of the earlier, basic model -- its correspondence with the state of the orginating science . . .
>
> In the third and current phase, of which BSCS is a part, two new developments are taking place. First, the basic model left substantially unchanged in the second phase, is being radically reordered. Second, those that led to the modifications of the second phase on the other are being brought to bear conjointly and in defensible relation with one another . . .
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> Here, then, is a rough picture of the pendulum swing which has characterized American education until recently . . . This pendulum swing is clearly evidenced in a study by William Brownson at the University of Chicago. He has found that better than 50 per cent of the authors of high school science textbooks available in 1915 were in the roster of American Men

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[1] Paul DeHart Hurd, Biological Education in American Secondary Schools, 1890-1960. Washington, D.C.: American Institute of Biological Sciences, 1961.

[2] Joseph H. Schwab, Biology Teacher's Handbook. New York: John Wiley and Sons, Inc., 1963, p. 3-8.

> of Science. In 1955, by contrast, the figure had dropped to less than 10 per cent.
>
> Clearly, neither extreme of this pendulum swing gives us good textbooks . . . . In brief, neither the old textbook nor the more recent one was satisfactory. Each had advantages, but each had weaknesses that might have been corrected by the influences which shaped the other. What was needed was a collaboration among the different competencies responsible for the different texts -- between the scientists on the one hand and the teachers on the other, between close contact with the field of knowledge and close contact with experience of and knowledge about teaching and education . . . Teachers now have come out of the schools; educators have come out of the colleges and universities; scientists have come out of their laboratories; the three groups together have begun to learn how to communicate and collaborate in producing materials for our schools.
>
> The BSCS texts are one result of this collaboration, because the BSCS accepted the obligation to bridge the gap between these indispensable sources of good educational endeavor.
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> Its aim was not merely to transcribe materials from the most recent scientific journals into textbook form but to select the materials most appropriate to the training of our youth; to develop and present these materials so as to contribute the development of attitudes and skills as well as of knowledge; and to recognize the fact that, for many students, the high school is terminal. The materials were not to be confined to elementary facts and generalizations; they were to constitute something broader and larger -- a reflection of the principles and emphases of the science as a whole.[3]

Dr. Arnold B. Grobman, Director, Biological Sciences Curriculum Study, was recently invited to appear as a witness to testify before the United States House of Representatives Subcommittee on Science, Research and Development. Among other things, Grobman discussed the subject, "How Content of Science Courses Was Determined Before the Advent of the Curriculum Studies."[4] These comments provide remarkably clear insight at the working level to problems of secondary education in the sciences and are quoted here because they demonstrate again the partnership of scientists and educators and because they may provide the background for some additional efforts that may profitably be developed within the various Centers for Science Education particularly with respect to research, diffusion, and adoption as defined in Professor Clark's paper previously given at this conference. Grobman said:

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[3] Ibid.

[4] Arnold B. Grobman, The Role of the National Science Foundation in the Improvement of Science Education in American Schools. Mimeographed Memorandum No. 228, BSCS Steering Committee (July 29, 1965), 1-7.

> It is traditional to emphasize that in America control of education is at the local level with varying degrees of coordination through state departments of education. Close inspection of one aspect of education -- high school science courses -- leads to some instructive insights on how course content is, in fact, actually determined.
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> Local School Boards: The local school board employs the science teachers and approves the selection of textbooks. But the board does not train the teachers nor does it write the textbooks. Although the local school board has considerable legal responsibility, the *de facto* determination of the actual content of science courses resides elsewhere.
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> State Departments of Education: The state departments establish criteria for the certification of teachers and could in theory, determine the kinds of training teachers receive. In practice, however, the state departments legislate in terms of course credit hours and it is in the universities where determination of the actual content of teacher instruction is made. Some state departments of education do exercise modest control over the content of textbooks by prescribing to publishers. In almost half of the states, the education department periodically stipulates one or more textbooks which schools may purchase with state funds and, thus, it could influence the curriculum to the extent that there are real content differences of a substantial nature among competing science textbooks. But study of available textbooks (from the period before the curriculum studies) does not reveal substantial differences among textbooks insofar as basic content is concerned. On balance, since the training of the teachers is the responsibility of the colleges, and the writing of the textbooks is in the hands of authors and publishers, the control and influence on course content in the sciences by state departments of education appears to be relatively minor.
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> Teachers: In theory, a high school science teacher has considerable freedom to determine the content of the courses he teaches. In practice, he teaches five, six, or seven classes a day for five days a week; grades the papers and reports of his students; arranges for his own laboratory materials and equipment; and is often obligated for certain extracurricular activities such as lunch room duty and monitoring study halls. Unlike his collegiate colleague,

the typical high school teacher has an assigned work load so overwhelming that, regardless of his honest intentions, he must depend very heavily upon textbooks for determining the content of his courses.

Publishers: In the initial plan for a new science textbook, the publisher and his authors design a book that is as educationally sound, up-to-date and effective as they can make it. I have tremendous confidence in the integrity, competence and ability of most American textbook publishers to produce educationally sound and stimulating books. When such books are placed on the market, however, there develops an effective influence on, and actual control of, content for which no name seems to be available. I use here the phrase "content determination by the non-academic market place" as a label to aid in examining this phenomenon.

Non-academic Market Place: The initially sound books placed on the market by the publisher bring him a variety of responses. One of the first is a series of negative reactions towards certain topics by small nonrepresentative groups in different parts of the nation. For example, the publisher of a good modern secondary school biology book is reminded, in one state, that his book would be quite acceptable if the topic of evolution were omitted because state law prohibits the teaching of evolution in the public schools. The publisher knows that the industry is highly competitive and that if he includes evolution in his book he will lose sales to competing publishers whose evolution-free books would be adopted instead of his. In another part of the nation, the same publisher is told that his biology book would be welcome except that the material on human reproduction "is a little too frank for our conservative community" and so he again faces the same kind of problem and usually arrives at the same non-academic solution. In other communities, additional controversial topics meet resistance and on most occasions the publisher reacts by modifying or omitting sections of his book in order to try to satisfy most of the special interest groups. He continues to make downward adjustments in content in order to drive his sales record upward. Relentlessly and predictably, in this fashion, a series of debilitating deletions is made by the publisher in his biology book. Resolutely this process continues despite the clear preference (subsequently demonstrated by the wholesale adoption of BSCS books) of the vast (and silent) majority of both informed lay citizens and educators for a sound scientific treatment of evolution, human reproduction, and other related biological topics, in a good high school biology textbook.

It should be understood that the question I am trying to illuminate is not whether evolution or human reproduction or any other specific topic should be taught in high school

> biology classes. The question is whether such determinations of what is to be taught should properly result from the pressures of small, non-academic, special interest groups. The end result of the process I have described is substandard educational materials for the nation.
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> Returning now to the publisher, his initially excellent plans for a fine book, when molded by the actual and anticipated negative pressure of the non-academic market place, frequently emerge as a lifeless compendium of factual statements without controversy, without vitality, and without interest. The various publishers' textbooks become safe, sterile and similar and not in the interest of superior education. They are bland and colorless, and the students who use them are largely unchallenged, uninterested, and unaffected.
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> *Curriculum Study Groups*: Most informed people would agree that the scholars in a discipline, and the teachers of that discipline, should cooperatively have a major voice in recommending the appropriate content to be studied in our schools. Biologists and biology teachers should recommend the model materials to be taught in biology classes; chemists and chemistry teachers, materials to be taught in chemistry classes; and mathematicians and mathematics teachers, materials to be taught in mathematics classes. In essence, this is the great contribution of the recent curriculum study groups, such as the Biological Sciences Curriculum Study (BSCS), the School Mathematics Study Group (SMSG), the Physical Science Study Committee (PSSC), and others. They have brought together the teachers and scholars in their respective fields and those scholars and teachers have prepared model high school courses with content appropriate for our present day and age. In making the majority of these materials available to the schools with the full cooperation of textbook publishers, the curriculum study groups have been acting completely within the traditional framework of local control of education, our free enterprise system, and the fundamental tenets of our American democracy. And they have been able to overcome much of the negativeness of the non-academic market place because NSF support has made it possible for the curriculum study groups to produce their materials independently of such pressures.[5]

In discussing the emerging role of the curriculum studies, Grobman said:

> Thus, for many years conditions have been ripe for the design of science curricula by scientists and science teachers. *Probably most of the innovators did not analyze the educational scene in the terms of the sketch above*;[6] they simply began with the blunt and

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[5] Ibid.

[6] Italics added.

> direct observation that our physics, chemistry, biology and mathematics courses were demonstrably substandard and that we had ample resources to do far better.[7]

It should be reasonably clear from the foregoing surveys and comments that change in the development of textbooks and similar curriculum materials during the period up to the advent of the national curriculum studies has been relatively slow and sometimes characterized by interruptions from special interest and pressure groups. But it is equally clear from the analysis given that changes in educational practice that can be brought about by use of these and similar curriculum materials and programs also can be made more effective by efforst of Centers for Science Education in research, development, diffusion and adoption of the programs. This statement does not imply blind or uncritical acceptance of the programs as they now stand, but it should be recognized that with the advent of these materials, new material is now available for evaluation and research as well as for diffusion and adoption, and in fact diffusion and adoption may be controlled or modified by the results of evaluation and research. Surely, potential activities of considerable importance in these areas constitute a role for the Center for Science Education. It should be pointed out that "blind or uncritical acceptance" of the new curriculum programs is not an objective of the curriculum study groups. The importance of research and evaluation by other groups has been stated positively by Hulda Grobman, BSCS Staff Consultant in an article, "Needed Research in High School Biology" soon to be pusblished in The American Biology Teacher.[8]

Brief mention, at least, should be made that the numerous technological advances that have shown up in radio, motion pictures, television, and other audio-visual equipment, as well as laboratory equipment and new computers should promote change in science teaching. Indeed these advances have promoted some changes, but far short of what might be expected. Why? The probable reasons vary. Again sometimes progress is stifled by the efforts of the special interest groups. Sometimes school officials pay handsomely for special equipment, but nothing for maintenance of the equipment and for the complementary facilities required for effective use. A continuing lock-step class schedule is commonly used and may hinder new program development. Perhaps more importantly, there is little or no support and few efforts made to educate teachers in the proper use of such equipment. Such a program of teacher education for science teachers also must involve a partnership among scientists, educators, and various other specialists to develop appropriate materials and techniques to make effective use of the equipment and facilities that may or can be made available. The potential for development and research in these areas for Centers for

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[7] Ibid.

[8] Hulda Grobman, Needed Research in High School Biology. Mimeographed Memorandum No. 1395, BSCS Evaluation Committee, Spring, 1965.

Science Education is considerable, but there appear to be few reports of significant work that has been done. On the other hand, the development and use of films has been a part of most of the new curriculum programs and their use in teacher preparation programs has been suggested in a progress report of the panel on Educational Research and Development by Jerome B. Wiesner, Chairman of the President's Science Advisory Committee at the time of the report.[9] It should be mentioned also that flexible time scheduling is included among suggested and needed innovations in a publication by Trump and Baynham.[10]

Certainly a review of the considerable money, time, and talent that has been used in special institutes for science and mathematics teachers could be expected to demonstrate change in educational practice. Indeed it appears to be obvious from both subjective and objective evidence collected over a number of years by the National Science Foundation that a marked impact has occurred in a number of areas. White summarized the results of a follow-up study of 1957 institute participants in parts as follows:

> Judgments of principals who weighed the value of institutes gave convincing evidence that their teachers who were attenders, as compared with non-attender teachers, were much more alert in keeping abreast of new techniques and in maintaining progress with the new subject-matter developments in their areas. A large majority of the principals have summarized their belief that the institutes accomplished their mission "very well." Strong preferences were expressed by principals for institute alumni. The principals gave credit to institute participants for improvement in a large number of virtues associated with good teaching: enthusiasm, interest in their subjects, ambition, willingness to learn new ideas, stimulation of better student interest, grade improvement, and encouragement of college-bound students to plan for careers in science . . . .
>
> There is general agreement among both principals and science teachers that there has been a material improvement in course content and teaching techniques among teachers who attended institutes. The teachers reported that new ideas are now more readily accepted, improvements are being made in their equipment, their students are better oriented toward

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[9] Jerome B. Wiesner, Innovations and Experiment in Education. Washington, D.C.: U. S. Government Printing Office, March, 1964.

[10] J. L. Trump and D. Baynham, Focus on Change: Guide to Better Schools. Chicago: Rand McNally, 1961.

> "hard" subjects, more science books are voluntarily being read, and better grades are being received in mathematics-science courses. Larger proportions of the school students now have more respect for science and science teachers than they had two years ago.[11]

Note particularily reference to "a material improvement in course content and teaching techniques." But it must be recognized also that almost none of these institutes represent any appreciable work of Centers for Science Education. It should be added quickly, of course, that by definition NSF support of such institutes is limited to science or mathematics staff and in general does not include education staff. The point to be made is not whether this situation is right or wrong, but that the staff members of Centers for Science Education should ask themselves whether or not they have a role to play in these activities and, if so, be able to define its nature. It well may be that as new centers are organized, potential answers to these questions may or should influence the objectives and organization of the centers. Perhaps it should be said that in some instances, at least, the center may need to earn its role to participate in these kinds of educational changes. Burnett showed clear insight into at least part of this problem when he said:

> We think we have plenty of empirical evidence that formal didactic instruction is a poor and inefficient way to engender conceptualization. But we really do not know -- and the past three decades of research in science education have not given the death blow to this method of teaching. Even today, we continue to teach teachers in science courses and in pedagogy largely through such nonheuristic means although we apparently suppose that this will somehow make them into effective teachers of the new programs which are based largely on the diametrically opposed other set of assumptions.
>
> It does not make very good sense.[12]

It may be noted also that Gruber found that participants in Academic Year Institutes at Colorado made no gain in understanding the nature of scientific thinking.[13] He concluded that a program emphasizing the products (knowledge) of science rather than the process of science has little effect on the teachers' gain in understanding science. Perhaps Centers for Science Education have as one opportunity the development of new strategies for better preparing science teachers by stressing the process approach to science.

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[11] Marsh W. White, A Review of NSF Summer Institute Program: A Follow-up Study of 1957 Institute Participants. Mimeographed Evaluation of the NSF Summer Institute Program conducted by the Bureau of Social Science Research, Washington, D.C.: National Science Foundation, June, 1960, 12.

[12] R. Will Burnett, "Circles, Pendulums, and Progress in Science Education," Journal of Research in Science Teaching, II (1964), 33-42.

[13] Howard E. Gruber, "Science Teachers and the Scientific Attitude: An Appraisal of an Academic Year Institute," Science. (August, 1960), 467-468.

Heisler made an appraisal of the first Academic Year Institute for High School Teachers of Science and Mathematics of the University of Pennsylvania.[14] The hypotheses tested were that after participating in an academic year institute measurable improvement would take place in knowledge and understanding of teaching and learning, and classroom performance. The sample consisted of 51 participants. The Graduate Record Examination Advanced Tests in Biology, Chemistry, and Mathematics were used in a pre-test and post-test design. The post-test scores showed superior achievement of the institute groups in biology and chemistry, and superiority of the reference group in mathematics and physics. Follow-up data regarding changes in patterns of classroom activities were inconclusive.

The apparent inconsistencies among reports such as those just quoted and those mentioned previously in this paper are probably due to the use of different evaluation techniques and instruments, and they certainly point to the need for more and better evaluative instruments -- an area where a partnership of science, science education, and psychology could contribute to research and hopefully to favorable change in educational practice.

In considering the role of the Center for Science Education in teacher education, one should ask what, if any, innovations are being attempted in either pre-service or in-service programs. Recently the Journal of Research in Science Teaching devoted an issue to programs for secondary school science education. Of the many interesting programs described, three will be mentioned briefly here.

Hurd noted that the Stanford Science Intern Program provides a fifth-year program of teacher education in the sciences.[15] The program presently accommodates approximately fifteen science teacher candidates each year. These interms are involved in continuous practice in teaching. The first phase of practice is known as micro-teaching. Micro-teaching is a scaled-down teaching encounter, scaled in terms of class size (1-5 high school students) and time (5-20 min.). The intern's performance is evaluated both by the students and the supervisor. The advantage of this phase of the program is in the reduction stimuli with which the novice teacher must cope with individually; also the supervisor can focus his supervision more precisely. Following micro-teaching, the intern is responsible for two classes at a school where the intern is placed for nine months.

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[14] Richard S. Heisler, An Appraisal of the Academic Year Institute for High School Teachers of Science and Mathematics of the University of Pennsylvania. Unpublished Doctoral Dissertation, University of Pennsylvania, 1961, 55.

[15] Paul DeHart Hurd, "Secondary School Science Teacher Education at Stanford University," Journal of Research in Science Teaching. III (1965), 122-126.

Burkman points out that as a result of experience gained while conducting training institutes for science teachers, the science education personnel at Florida State University have assumed the responsibility for 18 of the 25 semester hours of professional education required of prospective science teachers.[16] This procedure makes it possible to provide a specialized professional sequence devoted to the particular aims of science education. A part of the sequence consists of a course with three phases. In the first phase the philosophical foundations for science teaching are introduced and discussed. In the second phase, the instructor and students jointly prepare a one-week series of lessons which incorporate many of the philosophical ideas already discussed. After the development of the materials, the science education instructor teaches the program just developed to a group of high school students while his own students sit in the classroom and observe. After the demonstration the class reconvenes, and the effectiveness of the material and procedures is discussed.

Howe and Richardson describe the program at The Ohio State University.[17] A core of professional courses is required. These include a professional course concerning the teaching of science in secondary schools required as a first course in the science education sequence. This course:

> . . . . provides experiences in analyzing various science curricula and objectives of teaching science, planning and teaching for specific objectives of science, using various methods and materials for teaching science and evaluating learning outcomes. During this course university students work with secondary school students on an individual basis. This provides the prospective teacher with an application of previous professional learning and provides insight into the behavior, interests, and learning characteristics of the adolescent.
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> Three practicums in the teaching of science have been developed to provide for the unique needs of teachers

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[16] Ernest Burkman, "Secondary School Science Education at Florida State University," Journal of Research in Science Teaching. III (1965), 107-111.

[17] Robert W. Howe and John S. Richardson. "Secondary School Science Teacher Education at The Ohio State University," Journal of Research in Science Teaching. III (1965), 137.

> in several content areas. The basic idea in such a practicum is to develop in the prospective science teacher a competence in using the school science laboratory as his own professional research laboratory, a place where he and his pupils work together in problem solving. Separate courses have been organized for teachers of biology, earth science, and the physical sciences. These courses provide experiences in developing demonstrations, experiments, and other laboratory activities, in effective use of teaching materials, and in the development of techniques and skills needed for teaching each of the subject areas. The courses are taken preceding or concurrently with student teaching.
>
> To provide a realistic environment for the development of the science teacher's professional competencies, an array of materials and facilities must be available. The central facility in the Center for Science Education is a classroom-laboratory. The laboratory is equipped with facilities and materials typically found in well-equipped high school laboratories. An audio-visual room, a darkroom, a workshop, a teaching materials preparation area, and a science library are located in adjoining rooms. These provide the students in the courses concerning the teaching of science with additional facilities and resources which can contribute to effective teaching and learning.[18]

These undergraduate programs and others illustrate that new attention is being given to the science education programs of prospective science teachers. Some attention is being given also, but only recently, to the science course preparation of prospective science teachers. This attention is illustrated by recent efforts of The Commission on Undergraduate Education in the Biological Sciences (CUEBS). In particular, CUEBS has set up a Panel on Preparation of Biology Teachers and considers its area an important one in undergraduate education in the biological sciences. In a position paper developed by the Panel (to be published in an early issue of BioScience) the basic core program is discussed:

> Such a core, whether organized and taught as a series of coordinated courses, each under the auspices of a given department, as an interdepartmental program, or as a combination of these, should represent the major concepts, techniques and conclusions of biology and exemplify their interrelations. It should expose the modes of reasoning used in the context of representative investigations, and introduce the students to primary and secondary source materials. In general, all students specializing in biology, including potential teachers, would be expected to take the same course, although some might be accelerated

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[18] Ibid.

> on the basis of appropriate high school credentials or placement examinations attesting to superior pre-collegiate preparation. Specialization beyond the core will differ depending upon the professional goals of the student.[19]

The Panel has also considered "Methods Courses" and "Science Education Courses." The position paper states:

> Methods courses of special relevance to prospective teachers constitute an important area for experimentation. Such courses should involve the participation of professional biologists together with their colleagues from schools or departments of education. They should not confine themselves to the usual coverage of principles of teaching and learning, but should also consist of seminars in which various approaches, including programmed laboratory units, the use of original papers, an evaluation of existing visual aid material at various levels, available texts and laboratory manuals, are all examined and evaluated in a spirit of inquiry. There is a need for the development of courses of this type and for organizing the supporting materials on which they would be based . . . .
>
> Science education courses for secondary school teachers might profitably parallel the substantive college science courses by examining a representative diversity of school curricula in these areas at the time that the student is taking his college work in these same subjects. Such a plan would involve close cooperation between persons in the science and education departments, and, indeed, in schools. This cooperation should, in turn, produce some new departures in education courses and in school practices. We foresee many derivative dividends resulting from such a three-way liaison.[20]

Here again the cooperation of educators and scientists is emphasized and potential role of the Center for Science Education is obvious. What is not so clear, however, is what should be done concerning the low numbers of prospective science teachers graduating each year that have completed a science education program in many of our major institutions where such programs are offered.

Up to this point this discussion has been limited primarily to changes in science education during the past few years with a few "needles" that might stimulate future activities for centers in the development of science curriculum materials and the preparation of science teachers. It should be in order now to consider some current problems and potential activities for Centers for Science Education at a somewhat more advanced level of education and research.

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[19] Training the Modern Biology Teacher, a Position Paper by the Commission on Undergraduate Education in the Biological Sciences No. 12, George Washington University, Washington, D.C., August, 1965.

[20] Ibid.

Scandura and Nelson have noted that "the traditional role of the professor of science education has been to integrate, interpret, and disseminate relevant knowledge for practitioners.[21] Teacher training and the in-service education of teachers have been his major responsibilities." An additional area of responsibility that has been badly neglected is that of conducting research. Interdisciplinary teams have developed in many parts of the country to fill the need for research in science education. These teams have achieved notable success in a number of instances. However, there exists a need for specially devised graduate programs featuring sound interdisciplinary courses of study, and research experiences which will provide subject matter for educators with the skills and insight in the area of subject matter research. Programs of this type will require the inclusion of research specialists in departments of science and mathematics education.

The Final Report of a Special Committee of the Association for the Education of Teachers in Science stated that ". . . the only acknowledged and long term sources of persons explicitly trained to provide continuing leadership in science education are the many doctoral programs in science education."[22]

It may be of interest, then, to compare doctoral program potential of a given Center for Science Education with that suggested by the special committee. It is beyond the scope of this paper to list the "standards" and to present other significant details in this report. Dr. James Rutherford, Graduate School of Education, Harvard University, served as chairman of that committee and perhaps can provide additional information for those who may be interested. The point to be made here is the importance of linking programs of graduate study and programs of research within the framework of center organization and operation.

Johnson, Obourn and Blackwood suggest that "one field for investigation" in science education can be stated in the form of a question: How can the results of science education research on curriculum problems be more effectively interpreted and disseminated so as to result in the improvement of the science curriculum at each level?[23]

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[21] Joseph M. Scandura and Jack L. Nelson, "The Emerging Role of the Subject Matter Educator," Journal of Research in Science Teaching, III (1965), 51-53.

[22] Standards for the Doctorate in Science Education. Mimeographed Final Report of a Special Committee of the Association for [illegible] Education of Teachers in Science, March 31, 1965.

[23] L. K. Johnson, E. S. Obourn, and P. E. Blackwood, Research in the Teaching of Science. U. S. Department of Health, Education, and Welfare, Bulletin No. 10. Washington, D.C.: U. S. Government Printing Office (1965), 144.

Pella identified the number one problem in science education as complacency on the part of significant numbers of scientists, science teachers, administrators, engineers and industrialists.[24] Part of the cause of this complacency was attributed to the mistaken belief that the adoption of the "new courses" had solved the problems.

Belanger notes that although the past decade could be characterized as a period of extensive curricula development in science, another avenue of endeavor has also been accelerating.[25] This effort has to do with the classroom behavior of teachers.

The National Science Teachers Association Curriculum Committee suggests that "the success of a new curriculum greatly depends upon how it will be taught. A curriculum reform is as much a matter of improving instruction as it is a re-evaluation of course content."[26]

To assume a responsible role in bringing about the changes necessary for the solution of these problems as well as others discussed in previous papers implies a responsibility for going beyond the initial steps of basic teacher education, developing new curriculum materials, or other innovations, and informing the science teaching community of such developments. The responsibility involves development, research, and evaluation, and, in addition, the execution of strategies to evoke the changes in educational practice that these activities should bring about, Theory Into Action in Science Curriculum Development discusses these strategies. It presents three phases of work which are designed to: (1) identify the broad principles that can apply to any or all curriculum development efforts in science; (2) call attention to the promising aspects or issues of science teaching; and (3) suggest approaches to local action programs for teachers, educators, and curriculum workers at all levels.[27]

Part One presents a logical plan for science teaching that is consistent with the structure of science and a modern view of science education. Part Two consists of a set of major conceptual schemes or big ideas that serve to summarize the structure of science. Part Two also identifies major items in the process of science. (It should be noted that the particular selection of these ideas has been criticized by Glass in an article published in The Science Teacher.[28] However, it is the general strategy suggested by Theory Into Action, not the major conceptual schemes, *per se*, that is most pertinent here.) Part Three of this innovation suggests approaches to be used in a local action program.[29]

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[24] Milton O. Pella, "Some Problems in Science Education," Journal of Research in Science Teaching. III (1965), 90-92.

[25] Maurice Belanger, "The Study of Teaching and the New Science Curricula," The Science Teacher. XXXI (November, 1964), 31-35.

[26] Theory Into Action in Science Curriculum Development, NSTA Curriculum Committee. Washington, D.C.: National Association of Science Teachers, 1964.

[27] Ibid.

An example of a specific program underway that utilizes the strategies under discussion here is the San Antonio Chemistry Project directed by Dr. Paul Westmeyer, Science Education Center, and Dr. Jefferson Davis, Department of Chemistry of The University of Texas.[30]

This project may be characterized as a strategy which involved systems in the environment, in this case, the project directors from The University of Texas, new chemistry curriculum materials, and financial support from the National Science Foundation. The new structures within which the project operated were an in-service program which operated concurrently with a pilot program of chemistry instruction for both chemistry teachers and their high school students. The stages in the strategy included: (1) design of innovations by project participants, directors, and school personnel; (2) local awareness-interest promoted by brochures describing the proposed project and through a series of meetings involving various elements of the overall project; (3) local evaluation of the efficacy of the project made possible by a series of preliminary meetings for the potential project participants at which time the proposed design of the project was discussed and modifications were incorporated; and (4) trial of this innovation (e.g., cooperatively tailored modern chemistry course) involving nineteen high school chemistry teachers and some 2,000 students. The design of the project provided for concurrent discussion of basic principles, evaluation of course organization and design of new approaches which were subsequently tried out in the classroom.[31]

A strategy of the type described above emphasizes the importance of local control and of active involvement in decision making of those who are affected by the decision. Miles also points out that:

> . . . . the ultimate aim of any particular strategy is to gain adoption of an innovation by a target system (school, college, etc.), though shaping and development

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[28] Bentley Glass, "Theory Into Action -- A Critique," The Science Teacher. XXXII (May, 1965), 29.

[29] Theory Into Action in Science Curriculum Development, *op. cit*.

[30] Paul Westmeyer, "School-College Cooperation in Chemistry Course Development," The Science Teacher. XXXII (April, 1965), 33-34.

[31] Ibid.

> of innovations are of course likely during the adoption progress . . . . The question of adoption and continuation begs the more fundamental question, the one which an innovator's proponents usually answer automatically and positively: *Is it really effective*?. . . . Educational innovations are *almost never* evaluated on a systematic basis . . . . "the creators of experimental programs . . . have little question about the efficacy of the changes they have introduced. They *know* that the courses they have developed are the best possible under existing conditions; and in the light of this assumed fact . . . . systematic evaluation seems superfluous . . . .
>
> In the absence of evaluatory evidence, substitute bases for judgment are used such as educational ideology, sentiment, persuasive claims by advocates or salesmen. Most educational decisions appear to be made in an intuitive, prudential manner. Frequently, the opinions of users and clients are invoked. Informal student reactions and teacher responses are assessed; perceived student boredom is taken as an indicator of lack of learning, and the extra enthusiasm of teachers and students usually found in a new program (with its additional encouragement, recognition, and shared wishes for goal accomplishment) is mistaken for the success of the innovation. Quite often *no hard data have been collected* and decisions to terminate or continue the innovations are founded on sand. . . . . .
>
> This situation can be illustrated by an example. In April, 1961, the California State Department of Education initiated an evaluation of Title III of the National Defense Education Act to determine its effects on the schools in California, and to obtain information to improve its administration of Title III projects in California. Of the 1,507 usable responses from school administrators, only 68 gave an affirmative response to the question, "Have you evaluated any of the changes you instituted by means of scientifically designed and controlled research?" When these 68 responses were analyzed in terms of meeting the usual requirements of "scientifically designed and controlled research," less than 10 of the 68 qualified. Thus, less than 1/2 of one per cent of the responses described a clinical attempt to evaluate the effectiveness of a changed program.[32]

Miles also indicates a number of reasons for the infrequency of evaluation of a changed program in the schools. These reasons include:

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[32] Matthew B. Miles (Editor), *Innovations in Education*. New York: Bureau of Publications, Teachers College, Columbia University, 1964, 631-662.

1. few clear criteria of educational effectiveness,
2. adequate evaluation of an innovation is expensive in time and money,
3. difficulty of maintaining a controlled situation in the school,
4. systematic evaluation might prove risk-takers wrong and dampen the satisfying ardor of the mutually converted,
5. struggles for organizational autonomy and economic security may well be more potent that the question of the actual educational legitimacy of the innovation as such.[33]

The determination of the effectiveness of a changed program in a target school is a difficult proposition. In conferences of directors of course content improvement programs sponsored by the National Science Foundation, questions are frequently raised about evaluation. Cronbach commented on many of these questions and also on questions that should be asked concerning evaluation.

> In evaluating today's new curricula, it will clearly be important to appraise the student's general educational growth instead of evaluating solely on the mastery of the specific lessons presented. An example of this trend is BSCS which offers three courses each with substantially different "subject matter" as alternative routes to much the same educational ends.
>
> Aspects of each of these three courses may be tested by the same instruments.
>
> Evaluation can perform its greatest service in course improvement by identifying aspects of the course where revision is desirable and to perform this service when the course development project is still in a fluid, amendable state.
>
> Evaluation studies should go beyond reporting on the relative success of a program and perhaps yield insight in the area of educational learning.
>
> The systematic observation of a particular curriculum might include the following approaches: (a) process study which is concerned with events taking place in the classroom, (b) proficiency and attitude measures of pupil change, (c) follow-up studies of the later careers of those who participated in the study.[34]

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[33] *Ibid*.

[34] Lee J. Cronbach, "Course Improvement Through Evaluation," *Teacher's College Record.* LXIV (May, 1963) p. 672-683.

Miles points out that:

> The diffusion in educational systems may be slower than those found in industrial, agricultural, or medical systems for several reasons:
> (a) The absence of valid scientific research findings.
> (b) The lack of change agents to promote new educational ideas.
> (c) The lack of economic incentive to adopt innovations.[35]

We might also consider the possibility that certain ideological beliefs in the educational profession serve to block effective innovation by effectively insulating educational practitioners from reality. One of these protective myths is that teaching can never be effectively measured or specified in other than intuitive terms.

In conclusion, the role of Centers for Science Education in changing educational practice is big and it is complex, but it is a real role and a challenging one. However, it is not a road to travel alone -- it requires a multiple partnership, and it is a frontier road. The changes that have occurred will go almost unnoticed compared to the ones beyond the frontier.

In 1959, the President's Scientific Advisory Committee prepared a Report for the White House on Education for the Age of Science. It said, in part:

> In a frontier society, such as that of America of 100 years ago, it was natural that physical prowess and bravery, inherent in the pioneer, should have been held in high esteem. Today the frontier is intellectual; the scholar, the research worker, the scientist, the engineer, the teacher are the pioneers.

All of us are in one or another of these categories. At the intellectual frontier, cooperation is important as it is at other frontiers. The Center for Science Education can offer an opportunity for all of these pioneers - the scholar, the research worker, the scientist, the engineer, and the teacher - to work together to bring about desirable change in educational practice.

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[35] Ibid.

CENTERS FOR SCIENCE EDUCATION IN COLLEGES AND UNIVERSITIES

FUNCTIONS AND DESIGNS

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INTRODUCTION

The improvement of science teaching through the education of teachers, supervisors, and other personnel; research; curriculum development; dissemination and adoption; and various other activities is receiving greater emphasis and support in many colleges and universities. Institutions have shown increasing recognition of the need for assuming more responsibilities in these and related areas by commitment of personnel, facilities, and materials.

In a number of institutions, departments or areas of science education have been organized. These units have usually been assigned specific responsibilities and assumed others. Special facilities have also been provided to enable the faculty to develop an effective science education program through teaching, research, and service. At some institutions personnel and facilities have been provided to enable the development of a complex known as a center for science education.

During the past ten years the number of centers has increased rapidly. While most of the centers were first developed at larger public and private institutions, some have also recently been established in smaller colleges and universities. With the evolution of these centers, it has become increasingly apparent that they can provide personnel, facilities, and services needed for producing desired changes in the teaching of science.

THE PROBLEM

One activity of the project staff has been to assess the current status of centers in the United States. The problem was to identify institutions with centers and the functions and organizational designs of these complexes.

IDENTIFICATION OF INSTITUTIONS AND COLLECTION OF DATA

The first activities of the project staff were to review the literature from 1950 to 1965 related to science education; to contact persons active in the field; and to review catalogs of institutions throughout the country to identify institutions which had been involved in teaching, research, and service in science education. This search produced a list of 91 institutions which had substantial visibility on a state or national basis.

An inventory was mailed to each of the institutions to obtain desired information. When a person who was currently responsible for science education could be identified, the inventory was mailed to him. When such a person could not be identified, the inventory was mailed to the dean of the school or college of education of the particular institution. Seventy-five questionnaires and/or letters were returned from the original mailing. Follow-up requests obtained six additional questionnaires and/or letters for a total response from 81 institutions out of 91 originally contacted; a return of 89 per cent.

Data for the study were also obtained from catalogs, additional printed materials describing the institutions, further correspondence, and visitations by the project director, co-director, or a representative to many of the centers.

ANALYSIS OF DATA

Departments or Areas for Science Education

A question which is often raised by persons both within and outside the field of science education is whether institutions have departments or administratively identified areas responsible for the preparation of science teachers. The analysis of the data indicated that 40 or 49 per cent of the responding institutions had administratively identified units with designated responsibility for science education activities.

Analyses of the review of the literature and of other data obtained during the past year indicated several interesting relationships. Institutions with administratively identified departments or areas have generally been much more active in the production of doctorates in science education than have those without such departments or areas. Science education faculty members in institutions with administratively identified areas or departments have also been more active in research activities than persons from other institutions. A third interesting relationship which was established was that nearly all centers were located in institutions with an administratively designated unit for science education.

Number of Faculty Assigned to Science Education Administrative Units

The number of permanent faculty positions assigned to each science education unit was analyzed to relate the size of the units to data concerning functions and designs. Table I presents the full-time faculty equivalents and the number of institutions in each category.

TABLE I

NUMBER OF FACULTY EQUIVALENTS ASSIGNED TO SCIENCE EDUCATION UNITS IN VARIOUS INSTITUTIONS

Number of Full-Time Faculty Equivalents	.5 to 1	1.25 to 2	2.25 to 3	3.25 to 4	Over 4
Number of Institutions	9	12	6	3	10

An analysis of the data in Table I indicated that approximately 50 per cent of the science education units had two or fewer full-time faculty equivalents. While several of the smaller units had centers, most had been organized in the last few years. Several of the smaller units indicated plans for increasing their operations as faculty could be obtained.

Institutions Having Centers for Science Education

Table II presents data obtained concerning the institutions which had centers. A total of 33 centers were identified.

TABLE II

COMPARISON OF SIZE OF SCIENCE EDUCATION ADMINISTRATIVE UNITS AND THOSE POSSESSING AND NOT POSSESSING A CENTER FOR SCIENCE EDUCATION

Number of Full-Time Faculty Equivalents		.5 to 1	1.25 to 2	2.25 to 3	3.25 to 4	Over 4
Science Education Units Possessing Centers	Yes	5	11	5	2	10
	No	4	1	1	1	0

An examination of the data indicated the smaller units often did not have centers, while nearly all units with two or more full-time equivalents did. Nearly all the units with centers had responsibilities for both elementary and secondary science education. Several of the units also had responsibility for mathematics education and/or science courses. The smaller institutions which did not have centers usually had responsibility for elementary or secondary science education, but not both.

Administration of Centers for Science Education

Centers were operated by three general administrative patterns. Twenty-two of the centers were administered through a college, school, or department of education. Eight centers had a dual administrative relationship in which the center was related administratively to both a school of education and a school of science. Three centers were administered through a school of science.

Centers with more than three faculty members exhibited several differences in their administrative and operational patterns when compared to the smaller centers. Nearly all the larger centers identified extensive involvement of persons from both professional education and science in their activities. It was stressed by the respondents that joint activity was needed to develop good relationships. The analysis of the data indicated that most of the larger centers either had a Science Education Advisory Committee composed of personnel from the sciences and education, or were administered on a dual relationship. The larger centers also involved science personnel to a greater extent on Master's and Doctor's committees than did the smaller institutions.

Faculty Assigned to Centers for Science Education

Each inventory requested information relative to the academic preparation of faculty members assigned to science education activities. When these data were analyzed it was apparent that the current pattern of building a center faculty is to bring together persons with complementary preparation and experience. Thus, centers are tending to staff positions with persons having extensive science preparation in the biological sciences, the physical sciences, the earth sciences, and mathematics if included in their center activities. They also are assessing their faculty to have persons with teaching experience at the elementary, secondary, and college levels. Several centers are adding a third dimension in the analysis of staff needs. They are seeking to include faculty with varying research competencies, curriculum development competencies, and supervisory competencies.

The development of a center faculty which focuses on providing for these three dimensions should bring together persons who could develop an effective science education program of teaching, research, and service. Through cooperative activities they could focus on science education problems which extend across subject-matter boundaries and grade levels.

Facilities in Centers for Science Education

Data concerning facilities in centers are presented in Table III. These data indicate the presence or absence of each of the items, but do not indicate the amounts or quality of each.

An examination of the table indicates that nearly all centers possessed at least one classroom-laboratory. Pictures, drawings, and

TABLE III

FACILITIES LOCATED IN CENTERS FOR SCIENCE EDUCATION

Number of Full-Time Faculty Equivalents	.5 to 1	1.25 to 2	2.25 to 3	3.25 to 4	Over 4
Number of Centers in Each Category	5	11	5	2	10
Centers with at Least One Classroom-Laboratory	4	9	5	2	10
Centers with at Least One Preparation Room	4	6	5	2	9
Centers with a Workshop or Workshop Area	2	6	3	2	8
Centers with a Center Library or Library Area	4	8	5	2	10
Centers with a Darkroom or Darkroom Facilities	2	7	4	2	7
Centers with Special Facilities for Research in Science Education	3	4	4	2	7

visitations indicated differences existed in the number of classroom-laboratories at each center and also the size, location, and efficiency of the laboratory space. While a few centers had two or more well designed laboratory facilities, several had classroom-laboratories which were not located close to other center facilities. A number of laboratories used for science education classes were also smaller than desirable and lacking basic equipment needed for exploring a variety of teaching techniques in a classroom situation.

Table III also indicates the number of centers in each category which had workshops, library areas, darkroom facilities, and space for science education research activities. The data revealed that the centers with more faculty members usually possessed a greater number of facilities which are needed to provide the undergraduate and graduate student with a variety of experiences related to the teaching of science. Discussions with directors of centers and department chairmen indicated that the larger centers developed their faculty and facilities over a period of years and enlarged their programs as money and facilities became available. Several of the smaller centers reported the probable acquisition of remodeled facilities or plans for construction and appear to be in the process of providing more adequate resources.

The size and functional design of each of the facilities also varied extensively. While some institutions contained separate rooms which were adequately equipped and conveniently located, others had only limited equipment and often an area in a room devoted to the facility, rather than an entire room. The facilities of a few of the smaller centers would be evaluated as extremely meager and probably inadequate.

Reports and observations indicated that resources for research and curriculum development activities were being increased in several centers. These facilities included laboratory space, office space, calculators, reference areas, materials, and other items. In most instances the expansion has been funded at least in part by funds from the National Science Foundation or the United States Office of Education.

The inventories, reports, and visitations clearly indicated that most center personnel believed that a complex should be equipped to provide the student in science education with a variety of experiences related to the teaching of science. The majority of the centers are working to evolve complexes with the facilities listed in Table III, plus others which they deem desirable. Among other facilities in center complexes are greenhouses, animal rooms, field laboratories for use by science education students, display areas for science equipment, and facilities for radiological experimentation.

Data also indicated that efforts are being made to centralize the major activities of a center in one location when possible. Visitations and correspondence indicated that this is often achieved when a new building is constructed, but difficult to accomplish when expanding within existing facilities.

Teaching functions

All institutions with centers which responded had responsibilities for teaching undergraduate courses, graduate courses, or both. Table IV presents data concerning levels of courses taught by centers of various sizes.

Undergraduate science education course offerings varied extensively from institution to institution. A primary difference between many of the larger centers when compared to the smaller centers was the offering of a variety of special methods courses or practicums in the teaching of science. Several of the smaller centers indicated they planned to add

TABLE IV

LEVELS OF TEACHING AND DEGREES OFFERED BY CENTERS OF VARIOUS SIZES

Number of Full-Time Faculty Equivalents		.5 to 1	1.25 to 2	2.25 to 3	3.25 to 4	Over 4
Institutions Teaching Undergraduate Courses	Yes	5	10	4	2	9
	No	0	1	1	0	1
Institutions Teaching Graduate Courses	Yes	5	11	5	2	10
	No	0	0	0	0	0
Institutions Offering Various Degrees	Bachelor's	5	11	5	2	10
	Master's	5	11	5	2	10
	Doctor's	4	9	4	2	10

such courses as faculty and facilities could be obtained, but they currently did not have adequate faculty and/or facilities.

The larger centers also offered a greater variety of courses at the graduate level particularly in the areas of special methods courses, supervision, science curriculum, and doctoral seminars. When respondents were asked to identify changes they were planning in their programs, the small centers indicated course additions in the four same areas listed above. The most frequently identified categories were doctoral seminars and courses in supervision.

Responding institutions with centers all offered degrees to the Master's level. Twenty-nine of the 33 centers offered a degree at the doctoral level. Of the four which did not, two were planning to offer a doctorate program within two to three years.

Research Resources at the Local Institutions

The inventory requested information concerning the availability of various kinds of resources for research and development on the local campus. The data provided several interesting findings.

Nearly all the centers had experimental psychologists who were available to assist science educators on their various campuses. Twenty-eight indicated such help was available, while five stated help was either not available on campus or was extremely difficult to obtain.

A number of responders indicated difficulty in interesting the psychologists in working on research related to science education.

The report of activities at the various institutions revealed little research in science education actively involving psychologists. A few centers working on concept development, learning theory, and teacher behavior reported working with psychologists, but these were relatively few in number. This appears to be a resource area which needs to be developed to a greater extent.

All the centers reported that consulting assistance in research design and computer facilities were available on their local campuses. Several responders indicated that computer services at their institutions had to be purchased and were not available to the campus researcher even in limited amounts at no expense. Utilization of facilities in these instances depended on a source of funds to pay for desired services.

Extensive utilization of statisticians and computer facilities was evident from the inventory data. These services should permit centers to undertake research problems which would not have been feasible in terms of money, time, or design a few years ago. They also should enable a center to engage in research activities which personnel at smaller institutions could not conduct without assistance.

Nearly all centers reported working agreements with local schools which could be utilized for research by center faculty, though these resources had not been utilized appreciably except for student teaching and degree research. A few centers also had used local schools for curriculum development projects. Most centers did not maintain formal working agreements for research activities, but negotiated agreements as schools were needed for various activities.

Several centers possessed laboratory schools and stressed the opportunity these schools presented for a variety of research and development activities which could be conducted within their own facilities. Other centers indicated they previously had laboratory schools which they used, but that these either no longer existed or were being phased out, and that they would be attempting to develop working relationships with outside schools.

Research Activities of Center Faculty

It has often been reported in the literature that permanent science education faculty are not involved in sufficient research activity. One section of the inventory was designed to determine faculty research activity and areas in which they were currently active. The data indicated that one or more faculty members at 26 of the 33 centers were actively involved with personal research or curriculum development activity. Most of the centers in which faculty were not engaged in research or curriculum development activities were the centers with two or fewer faculty members.

Research activities of the center faculty tended to be clustered into eight major categories. These categories were the following: (1) evaluation of elements of the various science curriculum projects; (2) teacher behaviors; (3) concept development; (4) in-service elementary science programs; (5) reasoning, critical thinking, and inquiry; (6) education of science teachers (secondary); (7) development of instruments for evaluating learning related to science; and (8) research and development of audio and/or visual teaching techniques and materials. Many projects were also listed which would not be included in the eight listed categories. Thus, while activity was clustered in eight broad areas, there were also studies exploring other elements of the teaching of science.

Reviews of past research in science education have also discussed the need for cooperative action in research endeavors to fully utilize the talents of personnel and the kinds of facilities needed for various investigations. The inventory requested information concerning cooperative research activities with personnel from the local institution who were not assigned to science education activities. Data indicated that faculty members from 21 of the 33 centers were conducting cooperative research with local faculty. While personnel from centers of all sizes were engaged in these activities, 75 per cent of the centers with three or more faculty members were involved with local faculty in research activities. Involvement in cooperative research activities tended to increase with the size of the center.

Data were also obtained to assess the involvement of personnel from centers in cooperative research with personnel from other colleges, universities, and elementary and secondary schools. Twenty-two of the centers were involved in cooperative research with other institutions. Nine of the centers were involved in cooperative research with personnel in science education at other institutions; seven centers were involved in cooperative research activities with personnel from other institutions who were not involved in science education; 19 of the centers were involved in research activities and curriculum development with personnel from elementary and secondary schools. The analysis revealed that a greater percentage of the smaller centers were involved in cooperative research with other institutions.

It appeared to this investigator that research, development, and demonstration projects involving two or more centers or two or more institutions preparing science teachers could be utilized more effectively to improve research and its impact on educational practice. This statement is supported by the clustering of current research activities in certain areas with little apparent cooperative effort and also by the lack of contact between young researchers beginning activity in an area and researchers who have devoted considerable effort in the same area.

Activities Directed Toward Producing Educational Change

Science education should be concerned not only with research, but engineering of the research so that it can be translated into active use in the classroom. To move from the product of an investigation to influencing a change in educational practice would appear to require a number of operations such as those which are outlined by Professor David Clark in his paper.

To assess the kinds of activities being utilized by centers for demonstration purposes, responders were requested to indicate whether they had been engaged in demonstration activities and the nature of these activities. Twenty-seven of the 33 centers responded that they had been engaged in demonstration activities. Most frequently listed activities were serving as consultants in local schools developing curricula; holding in-service workshops for teachers with demonstration classes; serving as consultants to curriculum projects; demonstrating new curricula; directing institutes at which new materials and techniques are presented; distributing films which show new methods and techniques for teaching; and teaching new curricula materials in classes at laboratory schools which are open to observers. The larger centers indicated a greater variety of activities than did the smaller centers. The larger centers also had more activities of a planned, continuing orientation while the smaller centers more often utilized short-term activities.

Diffusion and dissemination activities used by the centers were also elicited from the responders. Twenty-nine of the 33 centers indicated they engaged in activities to disseminate pertinent research findings and curricular developments. Kinds of activities listed included teaching classes; speaking engagements; writing articles and books; providing in-service workshops; serving as consultants; using student teachers to present materials in local schools; directing institutes; and serving in the Visiting Science Program. Teaching classes, presenting speeches, and writing articles were the most frequently listed techniques for disseminating information. While most centers indicated a variety of methods, only a few had dissemination activities which appeared to comprise a continual, planned program. Follow-up visitations and conferences with personnel from a sample of the centers tended to support this judgment.

Patterns of Centers for Science Education

Table V presents an analysis of the patterns of centers which were identified and the functions emphasized by each kind of center. The writer of this paper believes that the centers with different patterns have different faculty, facility, and resource needs. The combinations needed depend upon the responsibilities and the functions of the center.

Most centers have emphasized the preparation of science teachers and science supervisory personnel. An effective design for a center emphasizing teacher education would include a faculty based on the three dimensions presented in this paper. Facilities comparable to those listed on Table III should be available to provide the students with a variety of experiences with teaching materials. An adequately staffed and well-equipped center of this type could provide a real impact on the preparation of teachers of science. A number of centers in the United States have made excellent progress in staffing their centers with persons having complementary preparation. Some centers have also developed adequate facilities and relationships to provide leadership in science teacher education.

TABLE V

PATTERNS OF SCIENCE EDUCATION CENTERS
PRINCIPLE ASSIGNED AND ASSUMED FUNCTIONS

	Pattern 1	Pattern 2	Pattern 3	Pattern 4	Pattern 5
Teaching					
Undergraduate	X*	X	X	X	
Graduate	X	X	X	X	X
Research and Development			X	X	X
Demonstration		X		X	X
Dissemination	X	X	X	X	X

*An X denotes area of concentrated activity.

A second function of nearly all the centers was the dissemination of pertinent research findings and curricular materials. An effective dissemination program would seem to require knowledge and materials of curricular developments in science education, working relationships or contacts with schools, and faculty time available to devote to these activities. In at least one of the patterns of centers identified in this study, very little material has been locally developed for dissemination. They rely on publications in the field or contacts with colleges, universities, and organizations conducting research or developing curricula.

Centers emphasizing dissemination activities have included among their efforts development of adequate curricular libraries available to local teachers, taking an active role in science teacher organizations, editing or contributing to journals, and organizing field service activities with schools. These activities are essential for communicating progress in science education throughout the country and should be included functions of the faculty of a Center for Science Education which truly serves as a center in its geographical area.

A third major function of several centers has been conducting research and/or curriculum development. A center which assumes these functions needs to have science educators who are competent, adequate facilities and resources, agreements with schools to provide student populations, and available faculty and assistant time. Centers in which faculty members are active in these endeavors have built much of their programs primarily through Federal project grants. These funds have enabled the centers to obtain released faculty time and needed resources. Most elementary and secondary school agreements have been limited to the geographical area in which the center was located except when the researcher or curriculum developer was involved in a project funded by NSF or through the U. S. Office of Education.

Demonstrating recent developments in science education is a fourth major function of a number of centers. Those centers emphasizing demonstration activities have many needs similar to those which are engaged in disseminating recent developments. These needs would include materials to be used and available student populations. While pattern two centers are nearly totally dependent upon developments produced by other centers or agencies, pattern four and five centers also have used considerable work from other institutions or organizations in addition to their own. Only a few centers have had planned demonstration programs. These designs have also seldom been of a cooperative nature with other centers except when the activity has been funded by the National Science Foundation or the United States Office of Education.

SUMMARY

Centers for Science Education provide a mechanism for strongly affecting educational practice. While these centers have provided leadership in several areas of science education, how to capitalize more effectively on the resources of the centers needs to be examined. Each center should evaluate its pattern of functions to determine whether it has provided a design which incorporates needed faculty, facilities, related resources, and services. Collectively we need to assess needs and actions which will facilitate our operations to meet the challenge of the future.

INSTITUTIONS WHICH PROVIDED DATA INCLUDED IN THE INVESTIGATION

Alabama

University of Alabama
Auburn University

Arizona

Arizona State College
Arizona State University

Arkansas

University of Arkansas

California

San Francisco State College
Stanford University
University of California
University of California at Los Angeles
University of Southern California

Colorado

Colorado State College
University of Colorado
University of Denver

Connecticut

University of Connecticut

Delaware

Delaware State College
University of Delaware

Florida

Florida State University
University of Florida

Georgia

University of Georgia

Idaho

University of Idaho

Illinois

University of Illinois
Western Illinois University
Northwestern University

Indiana

Indiana University

Iowa

Iowa State University
University of Iowa

Kansas

University of Kansas

Kentucky

University of Kentucky

Louisiana

Louisiana State University and Agricultural and Mechanical College

Maine

University of Maine

Maryland

University of Maryland

Massachusetts

Boston University
Harvard University
Massachusetts Institute of Technology

Michigan

Michigan State University of Agriculture and Applied Science
University of Michigan
Wayne State University

Minnesota

University of Minnesota

Mississippi

Mississippi State College
University of Mississippi

Missouri

University of Missouri

Montana

Montana State University

Nebraska

University of Nebraska

Nevada

University of Nevada

New Hampshire

University of New Hampshire

New Jersey

Rutgers, The State University

New Mexico

University of New Mexico

New York

Cornell University
New York University
Teachers College
University of Buffalo

North Carolina

State College of Agriculture and Engineering
University of North Carolina Chapel Hill

North Dakota

University of North Dakota

Ohio

Bowling Green State University
The Ohio State University
University of Toledo

Oklahoma

Oklahoma State University of Agriculture and Applied Science
University of Oklahoma

Oregon

Oregon State University
University of Oregon

Pennsylvania

Pennsylvania State University
University of Pittsburgh
Temple University

Rhode Island

University of Rhode Island

South Carolina

University of South Carolina

South Dakota

University of South Dakota

Tennessee

George Peabody College for Teachers
University of Tennessee

Texas

North Texas State University
University of Houston
University of Texas

Utah

University of Utah
Utah State University of Agriculture

__Vermont__

University of Vermont

__Virginia__

University of Virginia

__Washington__

University of Washington
Washington State University
Western Washington State College

__Wisconsin__

University of Wisconsin

__Wyoming__

University of Wyoming

STRATEGIES AND DYNAMICS IN CHANGING EDUCATIONAL PRACTICE

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A PERSPECTIVE ON EDUCATIONAL CHANGE

To some educators, albeit a decreasing number, the systematic discussion of strategies and dynamics for effecting planned change in schools is an uncomfortable notion. The very concept smacks of external control of the educational enterprise by a group of self-styled experts who will enlighten the uninitiated. The very language of those who have studied the change process reinforces this feeling as they discuss change agents, change mechanisms, and, worst of all, target systems. Educators are reminded, and often rightly so, of rigid master plans which have been constructed to facilitate school district consolidation or to enforce other aspects of state foundation programs.

Before embarking on a discussion which will employ some of these self-same obnoxious terms, it may be well to orient the discussion to the basic perspective of the author. Change is occurring in schools and school systems daily. The question, then, is not whether change will occur, but what the rate of change will be, what the nature of the changes will be, and where the origin of the changes will rest. In responding to such questions, sociologists have coined the term "planned change" which is simply an effort to distinguish activities in a social process field for which someone or some agency has taken responsibility, in contrast to random or naturalistic changes which all organizational systems undergo solely as a consequence of their existence as a system. The term has no inherent political ramifications and is, in essence, a sociological rather than a political concept.

In practice, of course, the distinction becomes less clear. Once a social process field elects to employ the concept of planned change to study itself and to plan for the future development of the field, it adopts certain strategies and techniques and these strategies and techniques have distinct political overtones for the field. The Elementary and Secondary Education Act of 1965 illustrates this point clearly. ESEA is an effort on the part of the Federal government to initiate a change strategy for the field of education. The Act is drawn to be responsive to existing legally constituted agencies in education (note, for example, the cautious application and distribution provisions of Title I and the effort in Title V to allow state education agencies to assume a full role in the change process), but it also introduces new structures to the field, e.g., the regional educational laboratories proposed in Title IV. Education will never again be quite the same as it was prior to ESEA though how it will be altered is, at present, dificut to discern.

This paper assumes that the path of the future for education will lie in a series of programs of planned change; that change as a phenomenon in education can be described and studied systematically; that the locus of change in education will shift from the single school or school district to inter-agency compacts of schools, colleges, and governmental agencies; that the specialist in education will assume a vigorous new role in this process; and, that as a consequence of these prior assumptions, education will improve at a greatly accelerated rate.

PLANNED CHANGE AND SCIENCE EDUCATORS

The events of recent years in science education have illustrated clearly the impact of planned change on the field. The curricula developed under grants from the National Science Foundation Course Content Improvement Section have had a profound effect on what is going on in local school districts across the country. The adoption of similar patterns by the United States Office of Education indicates an acceptance of the general role of the *ad hoc* committee or the inter-agency organization as a powerful change mechanism in education.

With or without the active participation of the educational specialist such programs appear certain to continue and flourish. They are, in a sense, the response of the Federal government to the challenge of planned change in education. Without the educationist, such efforts will be far less than satisfactory. Now is the time for the science educator to move vigorously to establish a new level of maturity in the research and development programs for education; a maturity which finds the scientist and the science educator working jointly on problems related to the development of the field of science education. This will require a commitment to the notion of planned change in education; abandonment of the long standing educational myth that each individual school district in this country can go it alone; and the establishment of inter-agency organizations which will be strong enough to mobilize the forces required to make a difference in schools. As this conference suggests, it may well be that the science education center located in institutions of higher education will be the base on which this inter-agency organization can be built.

A WAY OF VIEWING THE CHANGE PROCESS IN EDUCATION[1]

Despite a rich heritage of research on change in a number of social process fields, little is known specifically about how change occurs in the field of education. With the exception of the body of studies produced by Paul R. Mort and his students during the period 1935-1960,[2] this aspect of research in education has remained relatively virgin territory. Thus, the manner of viewing the change process proposed in this section of the paper will be primarily classificatory in nature and will be supported chiefly on the basis of empirical analysis in other fields of inquiry.[3]

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[1] This section of the paper draws heavily on a presentation made to the Seminar on Innovation in Planning School Curricula of the National Education Association's Center for the Study of Instruction: "An Examination of Potential Change Roles in Education," by David L. Clark and Egon G. Guba.

Figure I depicts a schema which has appeared to the author to have utility in viewing the change process in education. It contends that there are four identifiable phases or processes related to and necessary for change in education:

1. Research
2. Development
3. Diffusion
4. Adoption

Each of these phases (with the exception of research which for the purpose of this paper is considered a foundational condition) is further divided into stages which are purported to represent identifiable sub-processes in a program of planned change. In the further development of this section of the paper these phases will be defined and explained so that they can serve subsequently to analyze roles which science centers might play in effecting changes in educational practice.

First, there are three propositions underlying the schema:

1. That all social process fields must utilize a wide range of functions to develop and subsequently integrate new knowledge into more effective practice.
2. That these functions can be described and classified, and that appropriate criteria can be established in terms of which each phase can be evaluated.
3. That the change process can be depicted as quasi-sequential in nature but that the phases of the process are interrelated and mutually reinforcing and in practice their relationship is looping rather than linear.

The Research Phase

This is the one phase which, in the schema, is not divided into stages. Such a division could be accomplished through the application of conventional classifications of research, e.g., basic-applied, but there seems to be no necessity to do this, since a single objective, "to advance knowledge," covers the various stages which could have been used further to define the phase. Research provides the basis for invention, in a general sense, but the only criteria which can be used to assess research are internal validity -- the extent to which the hypotheses are tested or the questions are answered unambiguously, and external validity -- the extent to which the findings are generalizable to the population required by the hypotheses or questions being considered. This may be a mild overstatement of fact since questions of significance can be raised in relation to the problem being studied, but it serves to illustrate the point that research must be assessed in its own terms. Did the research, in fact, advance knowledge? is a question which can be answered without reference to whether the research affected practice. A "no" answer to the second question probably tells you nothing about the research. It may illustrate simply that development and diffusion mechanisms were not functional in the field in which the research was done. Often this has been precisely the case in the field of education.

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[2] Donald H. Ross, Administration for Adaptability. New York: Metropolitan School Study Council, 1958.

[3] See, for example, Everett M. Rogers, Difussion of Innovations. Glencoe, Illinois: The Free Press, 1962.

The Development Phase

This phase involves two stages -- invention and design. Invention is defined as the formulation of a new solution to an operating problem or a class of operation problems, e.g., team teaching as an antidote to some of the difficulties of the self-contained classroom unit. As Brickell notes in his monograph the conditions conducive to invention are quite different from those required by research.[4] It is equally true that the criteria which can properly be applied to these two functions differ sharply. On the face of it, does team teaching appear to be an appropriate attack on the weaknesses of elementary school classroom organization? Is there face validity in the idea? If one assumes that the teacher's lack of knowledge in a variety of fields is the basic weakness in the self-contained classroom, then team teaching appears to have face validity as an invention. What is the best, rough estimate one can obtain of its viability? If it increases school costs by 500 per cent it probably won't go any further. What is the best first estimate one can obtain of the breadth of its impact? Is it worth pursuing in terms of potential significance to education? These are admittedly gross criteria but at this stage of idea development they should be. It is certainly better to err on the side of permissiveness at the invention stage than to cut off good ideas because they cannot immediately be proven to be valid and viable.

A raw invention is typically unusable in a practical sense. To discover a chemical which retards the development of mold in bread is

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[4] Henry M. Brickell, Organizing New York State for Educational Change. Albany, New York: State Education Department, 1961.

FIGURE I

A CLASSIFICATION SCHEMA OF PROCESSES RELATED TO AND NECESSARY FOR CHANGE IN EDUCATION

	RESEARCH	DEVELOPMENT		DIFFUSION		ADOPTION		
		INVENTION	DESIGN	DISSEMINATION	DEMONSTRATION	TRIAL	INSTALLATION	INSTITUTIONALIZATION
OBJECTIVE	To advance knowledge	To formulate a new solution to an operating problem or to a class of operating problems, i.e., to innovate	To order and to systematize the components of the invented solution; to construct an innovation package for institutional use, i.e., to engineer	To create widespread awareness of the invention among practitioners, i.e., to inform	To afford an opportunity to examine and assess operating qualities of the invention, i.e., to build conviction	To build familiarity with the invention and provide a basis for assessing the quality, value, fit, and utility of the invention in a particular institution, i.e., to test	To fit the characteristics of the invention to the characteristics of the adopting institution, i.e., to operationalize	To assimilate the invention as an integral and accepted component of the system, i.e., to establish
CRITERIA	Validity (internal and external)	Face Validity (appropriateness) --- Estimated Viability --- Impact (relative contribution)	Institutional Feasibility --- Generalizability --- Performance	Intelligibility --- Fidelity --- Pervasiveness --- Impact (extent to which it affects key targets)	Credibility --- Convenience --- Evidential Assessment	Adaptability --- Feasibility --- Action	Effectiveness --- Efficiency ---	Continuity --- Valuation --- Support
RELATION TO CHANGE	Provides basis for invention	Produces the invention	Engineers and packages the invention	Informs about the invention	Builds conviction about the invention	Tries out the invention in the context of a particular situation	Operationalizes the invention for use in a specific institution	Establishes the invention as a part of an ongoing program; converts it to a "non-innovation"

one thing; to incorporate it into the process of producing and marketing bread is another. It is the design or packaging stage which orders and systematizes the invented solution into a package appropriate for institutional use. The best recent illustrations of attention to the design of an invention have been provided by the course content improvement projects of the National Science Foundation. The preliminary work of the Physical Science Study Committee (PSSC) invented a solution to an operating problem, i.e., updated substance for secondary school physics. Had the solution been left at this stage it is highly unlikely that it would have had impact on schools. After packaging in a usable and integrated form, however, it was ready for the processes of diffusion and adoption; and it has had a considerable impact on secondary education.

An even more telling example of the function of design in the innovation process is provided by standardized tests. It is doubtful if any area of educational research has had a greater influence on schools than that of tests and measurements. This would appear to be true precisely because the results of this research were designed, in the form of standardized tests, for use in the school setting. Had the results of this research effort not been engineered in the form of group tests, schools could hardly have been expected to do this for themselves, and the relevant content derived from these studies would now be summarized in a chapter of an undergraduate teacher education text on "Characteristics of Students."

Considerably greater precision can be brought to bear at this stage of development in establishing criteria and evaluating the product than was true at the invention stage. The pattern of evaluation typically followed is called field testing; its intent is chiefly to assess the feasibility of the design in an institutional setting, the generalizability of the design to diverse institutional settings, and the performance of the design, often relative to an existing design. Ideally, this field testing follows a period of intensive, small sample evaluation which the designers or engineers have conducted during the period when the design was taking shape. In a crude sense, this is comparable to the process employed by industrial engineers who seek naturalistic or uncontrolled settings to field test designs which have shown promise through controlled testing patterns, e.g., driving an auto whose components have been thoroughly laboratory tested across the country to determine its performance under real conditions.

The Diffusion Phase

The first state of the diffusion phase, dissemination, is concerned with creating widespread awareness of the existence and general nature of the invention among practitioners. When properly carried out, dissemination increases the number of options available to the professional, that is, it is not primarily a selling job on one idea. The criteria which can be applied to dissemination are essentially communication criteria: pervasiveness, the extent to which information has reached the target system; intelligibility and fidelity, the extent to which information has arrived in understandable and non-distorted form;

and impact, the extent to which information has affected the behavior of key targets. Note again the self-contained aspects of this stage in the process. The stage can be assessed in its own right. The process of dissemination does not purport to effect change in schools, but only to create widespread awareness of the existence of an invention.

The stage of diffusion labeled demonstration is more apt to be misunderstood than any other stage because of the loose way in which this term has been employed in education, e.g., demonstration schools (usually meaning university sponsored and housed elementary and secondary schools), or demonstration exhibits (usually offering testimonial to the effectiveness of a practice initiated in some institutional setting). In this case, the term means the provision of an opportunity for the target system to examine and assess the operating qualities of the invention. This implies interaction between the demonstrator or demonstration and the target system -- a real chance for evidential assessment of the invention by a competent professional. Certainly a demonstration, if nothing else, must be credible to the assessor or it loses all point. This can only lead to the conclusion that our continued use of typical schools such as laboratory schools as demonstration centers (not considering other uses they may have) has been and is incredible. Convenience to the target system is a relative criterion and included only because innovation research in other fields has indicated that target systems will not go out of their way to avail themselves of demonstration opportunities.

The criterion of evidential assessment require re-emphasis. Showing and telling is not demonstrating in the sense in which the term is here employed. The end result of demonstration, to build conviction on the part of the target system, can only occur in a legitimate professional sense if the target professional can undertake professional assessment; and he can only do this if the demonstration provides evidence which can be examined thoroughly and critically.

The Adoption Process Phase

Assuming that the target system is convinced of the efficacy of the invention there should be an opportunity to try out the invention, without substantial fear of failure, in the context of a particular institution. This trial period is not a period of simple "trial and error" but time during which familiarity with the invention can be established and during which a basis can be provided for assessing the quality, value, fit, and utility of the invention in a particular institution. Several general criteria can be applied at this stage. Is the invention adaptable to the characteristics of the local scene -- Does it have to be bought "whole hog" or not at all? If so, what impact will this have on local operations? Are there problems of feasibility not picked up in the earlier field trials? It may, for example, require a high level of professional performance in an area of marked weakness in the local system -- a weakness which cannot be quickly remedied. How does the invention act in this naturalistic setting with these professionals? This criterion is comparable to the earlier performance evaluation employed by the engineers who originally packaged the invention, but here the interest is in the action of the invention in relation to the particular circumstances of the adopting institution.

The trial stage has certain unique psychological properties that warrant its use even in cases where earlier field tests have left no doubt about the proper action of the invention in the local situation. The experimental air associated with trial has the same invigorating properties claimed by Stephen Corey for action research. Participation in trial experiences may persuade many otherwise reluctant adopters. Further, the trial experience may provide a kind of vicarious involvement with the invention that psychologically compensates the adopter for his possible lack of involvement in earlier research, development, or diffusion phases.

The process of installation, or fitting the characteristics of the invention to the characteristics of the adopting institution, may be an exceedingly complex and time-consuming stage. It may require substantial re-designing, extensive personnel retraining, or modification of other elements of the operating system which conflict with the invention. The criteria for evaluation are the conventional administrative criteria of effectiveness, the extent to which the invention accomplishes what it purports to accomplish in relation to the system's objectives, and efficiency, the extent to which these accomplishments can be achieved in relation to the system's available resources. The application of these criteria implies the operation of some pattern of quality control within the system which will allow for the measurement of impact of a change on the operating system. Without this quality control, an effective application of these criteria is nearly hopeless.

Finally, there is the process of converting the invention into a non-innovation so far as the adopting system is concerned. This implies establishing the invention over an extended period of time and valuing and supporting it as a regularly accepted component of the system. Whether this stage of institutionalization is, in fact, a part of the innovation process is a moot point debated by innovation theoreticians, but it is certainly a critical step in the process for the adopting system itself.

STRATEGIES FOR CHANGE IN SCIENCE EDUCATION

If a certain air of presumptuousness seemed to pervade earlier sections of this paper (i.e., attempting a classification schema for a process which is so modestly researched in education) watch out for the section which follows. The author is obviously inexpert in science education and the basis for identifying strategies will be the earlier propositions of the paper. If you are willing, however, to consider this as a stimulant to discussion, there may be some utility in having an outsider look briefly at some potentially powerful change strategies.

The Concept of Planned Change

At the broadest level of discussion, it might be helpful to reiterate the necessity for accepting a commitment to planned change in the field of science education. This concept implies planned intervention and demands cooperation which transcends individual efforts and cuts across institutional boundaries. No one advocates seriously a program for planning change which rests with a small clique of experts. The planning must engage the best minds the profession has to offer at all levels of specialization, i.e., teachers, science educators, and scientists. If the recent efforts in this field are to be criticized they must receive criticism for not having established this broad base of involvement. No single institution or agency can command this engagement of minds by itself. No single school system can afford to rely on its own resources for curriculum development. The growth, expansion, and development of the science education center concept, if such centers can be interrelated with a communications network, may be able to serve as a base for building this level of involvement.

Multi-function Process of Change

Perhaps the sharpest attack which can be mounted against previous change efforts in the field of education involves the oversimplified model of the process which has been employed. Educators debate seriously the question of why research has not influenced practice or why a concept introduced in science education courses is not found in field practice. Governmental agencies in education have adopted the so-called specialist pattern of staffing, have produced written materials on science education, and have rested in confidence that something would happen in the field. Science education centers staff up with one to three professors (according to Professor Howe's paper, 75 per cent fall in this category) and set out to change the world in science education.

If one accepts the multi-function paradigm employed in this paper as reasonably representative of the necessary functions to effect change in education, such modest, unitary efforts are bound to fail. A massive program is required and it must bridge the various phases of the process. Except in rare instances, schools will not adopt new programs on the basis of someone exhorting them to do better. They require a more sophisticated and intense level of contact and this requires, in turn, resources and activities of many types (involving the schools at many points) before an invention can hope to be diffused. Strategies and techniques should be developed to take account of the full range of the change process -- not a single phase.

Inter-dependency of the Phases of the Change Process

The several phases of the change process may not be sequential in a linear sense, but they are certainly interdependent. This implies, even demands, that an appropriate change strategy for the field will emphasize development of all the phases. Two recent efforts at effecting change in education provide cogent support for this point of view. Suppose, for example, that one were to adopt the NSF course content improvement efforts as the strategy for the field of science education. These projects have engaged in some modest evaluation efforts but, in essence, they are unrelated to any research in education. They are efforts to invent and design packaged programs which improve what is already known but they do not advance knowledge in the field. As is the case with all applied development programs they have built-in limitations to the extent that they cannot exceed what is already known. The end result of adopting such a strategy would be acceptance of the fact that what is now known about science education is the best that will ever be known. Educators would continue to refine the development of the kerosene lamp but electricity would never emerge from such efforts.

On the other hand, take the case of the private foundation which employs a strategy built almost exclusively on the diffusion process. Within a short period of time extant inventions become exhausted and the change agent finds himself attempting to diffuse highly debatable programs which have limited generalizability or questionable validity. It would be comforting and comfortable if it were easier to mount a change strategy in a social process field, but it is not. Attention will need to be given to each discrete phase in the process and some balance in the development of the phases will be required.

Research and the Change Process

Since the topic of research in science education has been covered so completely by Drs. Tyler and Williamson there is little point in dwelling on it again in this paper. Suffice it to say, again, that research provides the basis for invention in any field and that its growth in this field is assumed as a foundational condition for the change process.

Development and the Change Process

The primary role of the science education center may lie in the stages of invention and design. The conditions required for invention are hard to come by in operating situations since they involve freedom to err, rich resources in the environment, and relief from day-to-day operating pressures. Designing institutional packages is a tremendously expensive operation requiring a broad range of specialists and extensive field trial. Almost by definition, the school as an individual system cannot hope to create these conditions or sustain this operation. Probably the same can be said for a single institution of higher education but a federation of such institutions, with the active participation of the schools, could work effectively in this area.

Suppose, for example, the five cooperating science education centers with supplementary staff supported through outside funds were working on Project A. Each of the centers might be expected to develop and sustain *ad hoc* arrangements with 15-20 school systems which, in turn, could provide specialist staff to work with the invention teams at the centers, and serve subsequently as field centers for testing the institutional feasibility, generalizability, and performance of institutional packages. One could project a more complicated network of centers in which several projects are in operation at one time in several clusters of centers similar to those just described. Without belaboring the obvious, it is certainly the position of this paper that some such inter-agency arrangement will be required for the field of science education and that the centers have an opportunity to exercise initiative in this respect.

One parting note in this regard might be in order. There is a well-documented phenomenon of formal organizations which is labelled "goal-displacement" or as Berelson and Steiner define it, the ". . . tendency for organizations (of a non-profit character) to turn away, at least partially, from their original goals."[5] There are many and obvious examples of this in the field of education and these displaced goals are difficult to recapture because the ends which replace them become almost sacrosanct to the organization. Over a period of time, outsiders and some insiders viewing the organization, begin to use words like "the establishment" or "entrenched interests" to describe what they see. Those persons functioning within the organization may be equally perspicacious in identifying needed changes to reorient the enterprise to original and relevant goals, but they are also cognizant of the difficulty of doing this. With the best of intentions, the bureaucracy may crush the fragile programs of invention and design before they have an opportunity to develop. Inter-agency organization, or the creation of organizations parallel to but not a part of the legally consituted bureaucracy, is a tried and true technique for alleviating the pressure of the establishment _per se_. This phenomenon argues for and supports the earlier suggestion of relating science education centers to one another and to schools in a new and dynamic way.

Diffusion and the Change Process

The communications network employed in education can be faulted on several counts. At the initial point of consideration, storage and retrieval, the mechanism breaks down completely. Research studies are two to three years old before they are even reported in the accessible literature. The alert professional relies on an informal communications network with his colleagues to keep up to date on what is going on. If one could overlook this problem of storage and retrieval of required data, the form of dissemination would be sufficient to criticize. Researchers write for other researchers. The journals read by practitioners are filled with impressionistic and exhortative articles which are hardly on the forefront of knowledge. Reports on inventions often take the form of testimonials, the intent of which is to convince rather than inform. Enough of this self-castigation which has been said many times before. Obviously, an effective strategy for change will require a massive storage and retrieval program which can inform researchers, developers, and practitioners alike of current research and innovation in the field. And this network will demand new roles for educational personnel. The written word is not sufficient for the process. Some form of middle man will have to be available to translate the information into usable form and communicate it, often in a face-to-face situation, to practitioners.

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[5] Bernard Berelson and Gary A. Steiner, _Human Behavior: An Inventory of Scientific Findings._ New York: Harcourt, Brace and World, Inc., 1964, p. 366.

Demonstration programs require the same revitalization. The critical and hard to achieve criterion at this stage is the opportunity for evidential assessment. If educators believe honestly that they are dealing with professional colleagues in the process of change, then the diffusion phase involves interaction between professionals.

It seems wasteful to consider the diffusion phase in relation to science education alone. The Office of Education is in the process of establishing an Educational Research Information Center; there will be a national system of regional educational laboratories; school systems will be supported in setting up demonstration centers in cooperation with colleges and universities; individual institutions of higher education are already involved in reconceptualizing their arrangements and contacts with local schools and school systems to meet these challenges. Science education centers, particularly if they are tied together in regional and national compacts of their own, should be able to tie-in to these broader change programs, thereby saving duplication of effort while simultaneously strengthening their own programs and the programs of those agencies with which they relate. In all likelihood the future of the subject-centered change agency will emphasize ad hoc arrangements with schools while relying on more permanent school-university alliances built on a broad school improvement base to nurture change programs across the board.

Adoption and the Change Process

Anyone who has had experience in working in a public school setting will testify to the fact the distance between diffusion and institutionalization can look like the Grand Canyon. In the past, education has emphasized the one-shot relationship in fostering adoption of inventions through contract between university and school personnel. The professor has been viewed as a consultant who can be employed on an individual basis to work briefly with a school staff on the difficulties of trying and installing an invention. Or a survey team has been employed to legitimate changes which the school system already has in mind.

The school study council movement tried valiantly to intensify this level of contact between university and school personnel but failed substantially due to lack of resources and an effort to bridge the whole change process. Certainly new mechanisms are emerging under the impetus of ESEA and science education centers should find it possible to use these mechanisms effectively in assisting schools in the adoption process. Here again, it would seem to be strategic error for science educators to try to duplicate the broad range of new alliances and interactions which are almost certain to develop among researchers, developer, and practitioners.

CONCLUSION

To be personal for a moment, I hope this paper has not been too general for your purposes. As an outsider looking in, it seemed useful to attempt to provide a way of viewing the process of change in education and to introduce a few observations on the implications of this way of viewing for science educators.

The schema for change which was introduced in the paper seems important chiefly in terms of indicating the complexity of the process. Other formulations could be set forth with equal validity, modifications could be made in terms of specific phases or stages, and yet the overall burden of the discussion would still hold significance for planning for change in science education.

The same general point can be made in regard to the discussion of strategy for change. The naivete of the author in regard to the field may have caused oversimplification or even the statement of inappropriate strategies, but if they serve the purpose of eliciting alternate suggestions, they will have accomplished their end.

This is an exciting period in education to consider the question of change strategies because, for the first time, it is possible to anticipate that resources may match plans. The hope of this paper is to encourage the leaders in science education at this conference to think in new dimensions about what must be done.

SCIENCE EDUCATION CENTERS FOR RESEARCH AND DEVELOPMENT

Some Guidelines for Research Design and Action

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It seems evident that the furor attendant upon the first successful lofting of satellites, the threatened destruction of men and their things by other men and other things, and the charges and counter-charges of blame, negligence, and evil intent of those in government, politics, and education have leveled off and may even be declining. For those of us concerned immediately with our educational programs no sigh of relief is in order. We do have the reawakened interest and support of those with vision and energy; we do have the prospect of resources to support the various activities essential to the improvement of our educational programs. Now we must marshal our talents, refine our partial knowledge, and develop new knowledge. Our social conscience requires that we move promptly, cooperatively, and unselfishly toward a developing discipline of education and toward action programs in all arenas.

A prominent aspect of the total educational endeavor is that in science. Through science and through technology our insight into the nature of the most minute and most remote parts of our universe has been greatly extended. Unimaginable amounts of energy have become available. And, perhaps most hopefully, some progress seems to be identifiable in our understanding of how man's intellectual powers can be understood and made to yield greater future achievements than those in the past.

The role of science in the educational program has long been identified by the term, science education. Only in relatively recent years has it becone widely used, now serving as an umbrella for a wide variety of activities of a motley aggregation of persons in various professions. One of the results has been a variety of meanings, ranging from the broad improvement of the general scientific literacy of the public to the research and technical aspects concerned with teaching and learning, and with the influence of science as a process and as a product upon man, in school and out.

A need in this field has been recognized for several decades: our grasp of ability to improve and extend the research in science education has not equalled our reach. The solace offered in the literary reference is not satisfying to the inquiring spirit of the investigator in the field.

As we set about the task of moving toward an action program designed to improve research in science education and to bring the results of such improvement into play in man's educational endeavors, it is evident that certain guidelines to be observed in planning and conducting research and in the application of the results should be identified and explored. The guidelines that follow are submitted as being important and useful in the improvement of our research in science education. Such guidelines can provide an improved basis for action in both the production of research results and in their application.

Guideline I

In view of the fact that science education is a hybrid of the social sciences and the natural sciences the orientation of its research should reflect its inheritance from its parentage.

A clear requirement is that of interdisciplinary communication at levels of the philosophical foundations of objectives, society's requirements relating to literacy, and man's self-imposed task to learn more--to research--so that he can extend his own understanding and effectiveness and direct his energies with increasing confidence in his personal investment of time and intellect.

This communication can be identified as having the two parents, each of which is actually a broad and heretofore arbitrary classification of convenience -- the natural sciences, and the social sciences The subdivisions of each--the separate disciplines, if you will--are in no sense sacred entities They merely represent the interpretation that man has put upon information as he has come by it. He has classified that information as he has identified and depicted it in both qualitative and quantitative ways and thereby come upon some useful classification system or systems. Note that the motivation for classification is the hoped-for usefulness of that which is being classified. Systems of classification are perhaps best identified as monuments to utility While this viewpoint constitutes a denial of the concept of "natural relationship" or that of "studying science for science's sake" we have seen for several decades a progressive weakening of the walls of classical categories of knowledge. Today this movement seems to be under considerable acceleration.

Research in science education should now look, as never before at its general setting known as professional education, at psychology, sociology, and philosophy. These have been examined before, but separately, the singularity of purpose of the examination being, for example, "What can we learn from psychology?" This is laudatory, but we need to find the significance of the matrix; in oversimplified form, what are the developing relations between psychology and sociology that have significance for research in science education?

In a similar way, the science educator has often looked longingly at the physical or biological sciences for his models of research -- the objectives, the tools and processes and the organization and classification of his conclusions. Too often he has read the report of the research by a physicist or by a botanist, but has not found in it a delineation of what mental activity the physicist engaged in that drew perhaps on certain concepts in geology or in mathematics. Or the botanist may have drawn more than he himself realized on his understanding of certain chemical activities as they bore on the nature of the osmotic action in his cellular research.

The problem facing the researcher in science education, then, at this point is an identification of the various facets of our knowledge that have potential bearing on his research objectives, the processes, his resources, and the safeguards for his conclusions.

Guideline II

A second guideline is the ordering of purposes, plans, and outlines to meet the urgent need to find and establish an agreed-upon domain known as science education. Its concerns, activities, and resources should have enough in common to facilitate communication and cooperative action, without that arbitrary quality that leads to the building of walls which impede thinking and research.

The evolution of fields of intellectual effort and the varying degrees of accomplishment have caused the teaching profession to face a challenging task in any effort to synthesize elements of achievement in classifying information for interpretation. In the field of learning, professional education is a relative newcomer. Much of its knowledge is of empirical nature; the structure of this field, important and promising as the field is, is not well defined and the organization of its content is uneven and characterized by gaps and missing fields. As with any new and developing field of learning, such qualities are inevitable.

In a corresponding way the field identified as science education has a loose structure. This is ture to the extent that communication among those who seem to have common concerns in the field is sometimes difficult because of the lack of common experience, values, objectives, and vocabulary.

As in any domain, science education must develop a sphere of thought, influence, and action such that, as with the surface of its geometrical counterpart, it is finite but endless. The identification of such a domain will involve the interrelation in substantial measure of those elements of our learning that have not been traditionally synthesized but which can through adequate research be demonstrated to be interdependent and interrelated elements in our knowledge of man and the environment in which he finds himself.

Once this domain is so identified the first essential step will have been taken and the relationships of the various elements can then be subjected to research. We will then be able to move above and beyond fragmented and seemingly unrelated achievements.

While the evidence of the results of research efforts suggests that the direction that research may take reflects primarily the interest of the investigator, progress in the research productivity of science education seems certainly to depend on an identification of what we know with some confidence, of such interrelations of knowledge as can be established, and upon the prediction, hypothesizing and guessing as to potential areas meriting investigation.

Guideline III

The social significance of research can not be a step-child to the techniques and procedures used in the process of research.

If we accept the idea that research is an activity intended to increase one's ability to understand, predict, and control events and give to events the potentiality of variability of magnitude, form, and substance, then research becomes operationally the means of finding relationships between variables. The interpretation of this concept may range from that of the completely statistical, characterized by conventional relationships of cause and effect to that of the non-statistical, identified by new and unconventional relationships of the known, or accepted and familiar.

Between these extremes of interpretation is a continuum of activities, all properly identified (operationally speaking) as research. At the right, or conservative, end is dependence upon conventional mathematical operations in themselves requiring constant units of content behavior, the constancy being assumed from the origin and from identifiable qualities of the content units. At the left, or liberal, end is the non-mathematical, the unconventional, the creative, with variable units of content behavior.

In both of these extremes and in the intermediate points we find the establishment of relationships between variables. At all points value judgments have been invoked, and safeguarded interpretations have been drawn. The position on the right suffers from the assumed constancy of units of content behavior; that on the left suffers from lack of familiarity with unconventional, variable units of content behavior.

The hybrid parentage of science education has foisted upon the field an assumed prestigious position on the right, with a degradation of the non-mathematical or creative on the left. In this third guideline, research in science education must avoid the prejudicial positions which tend to warp that revered quality known as the open mind. In spite of the dictum that "knowing a thing is only partial knowledge until it can be described and defined quantitatively," there is no evidence that quantification is a prerequisite to a value; nor is there evidence that any or all values will yield eventually to quantification.

Guideline IV

The improvement of the research effort in science education and in the diffusion and utilization of the research product must be consciously planned. The identification of a domain of science education will have little value and the improvement of research in such a substantive domain will continue to be a difficult and inefficient operation until adequate plans for the preparation of researchers have been developed and the plans put into operation.

An early step in this phase is the selection of personnel to be prepared for various functions: teaching, supervision, teacher education, curriculum design, evaluation, and research. The improvement of preparatory programs for such functions will in itself depend upon research, followed by demonstration of the product, the diffusion of the findings, and their adoption by the preparatory agencies. The research necessary would seem certainly to depend upon both group and clinical as well as other techniques.

Guideline V

Science education researchers, along with others, should proceed to reassess the role of the various traditional classifications of research: philosophical, historical, normative or survey, clinical, developmental, and experimental. Aside from the dubious usefulness of these classifications to the researcher, two distinct disadvantages - even evils - have resulted from the identification, description, and specification of such rubrics.

No present assessment is available with reference to the inhibiting effect of an assumed set of "rules of the game;" this research was completed through a clinical design, let us say; what effect has this prior commitment had on the introduction of other concurrent designs? What potential gains have been by-passed through failure to introduce evidence through separate designs and separate tools?

A second problem, equally serious or perhaps more so, is the hierarchy of prestige that has been attached to the separate classes. Such associated attitudes cast serious doubt on the celebrated open mind of the scientist, a position revered also by the science educator. The too-prevalent reverence for studies classified as experimental has been accompanied by the degradation of those of the so-called normative or survey type; there have been corresponding levels of prestige for the classifications between the two extremes. The choice and use of tools and procedures tends to be limited in such an atmosphere, and to the extent that such hampering occurs the quality of the research suffers. Indeed, it is not far-fetched to assume that our relative lack of progress in our studies of creativity may have suffered by the arbitrary classifications of research procedure.

In the interest of brevity of statement, the assumed dichotomy inherent in the classification of research as basic or applied provides no assistance in the choice of methodology and creates hazards comparable with those classifications based on methodology as previously described.

The science educator can profitably study and employ, at least on an experimental basis, the methodologies which are derived from the objectives of the research inquiry as described and delineated by Clark.[1]

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[1] David L. Clark, "Strategies and Dynamics in Changing Educational Practice," (Paper presented at the Conference), 91.

Such a procedure provides for a taxonomy of objectives of instruction, as well. By observing not only the centrality of the research objectives and the dual nature of any such objective, the action aspect and the content aspect, a two-dimensional analysis can be derived. This categorization can be made to yield, presumably, all possible research actions. If so, such an approach can avoid most, if not all, of the weaknesses, a few of which have just been identified, in existing systems of classification.

Guideline VI

In keeping with the tenets of critical inquiry, all established findings of pertinent research should be available to a research study. The stipulation of pertinent research assumes, of course, that the nature of the research to be undertaken has not been biased by the investigator's predilection for a given problem or problem area, or for a particular research design, or by an arbitrarily identified system of analysis. Furthermore, pertinence stipulates certain criteria by which the investigator decided to include or exclude the evidence available from prior research. Among such criteria may be the organic relationships between the referent problem and that which is the subject of the projected research, the comparability of the factors in the research design, and the agreement between the analytical procedure involved in the referent research and that which is projected.

Thus, the identification of established findings assumes some form of support. This support may be based on some kind of evidence, such as replicated results. In other instances the support is in the form of a value system; such a system may range in its interpretation by researchers from philosophical imperatives to untested, and perhaps untestable, assumptions. Such variations or differences in the form of support for established findings raise questions requiring an answer: If replicability is essential to the acceptability of research findings, by what criteria does adequate replication occur? At what level of confidence does it occur? Such problems and quandaries may be difficult but are not necessarily insuperable.

More pertinent at this point is the provision for those leaps of imagination and insight through which hitherto unsuspected relations between two related events can be identified. Such identification is not, by any means, at the "demonstrated" or "established" level; it is at the "possible" level. It is the essence of the hypothesis.

From this view point then, the availability of pertinent established research findings necessarily incorporates the notion of attempting to bring together in some possible relationship all necessary and related events from the natural sciences and from the social sciences. Further, the notion would provide for the postulation of what might be considered a missing or needed event by which a relation could be established. In the interest of efficiency and effectiveness the possibility of certain or near-certain exclusion of some relations or categories of relations should be established.

Herculean as such a methodological approach seems to be, it has the merit, at least, of providing for our perspective the problems arising from the limited and piece-meal efforts of research in science education based on chance studies with or without any real basis of suspected relation between the events being studied. Its greater merit may rest in an approach to research through a general method of inquiry incorporating both the social and the natural sciences. A few tools, some of them relatively crude and unwieldy and others more sophisticated and more facile, are available. Such tools, and others hopefully better, will require improved methodology. Difficult as it may seem to be, the provision of the established findings of pertinent research seems to lie through such an approach.

A practical problem appearing at this point is the present relative lack of communication among the various disciplines and systems of knowledge. In many instances, events from one field can be interpreted only with much difficulty in another field. The availability of pertinent research, in both process and product, assumes facile and certain communication. The researcher as creator and interpreter then faces no particular barriers that separate disciplines and hinder inquiry.

SECTION V

SUMMARY AND RECOMMENDATIONS OF THE CONFERENCE

AN OVERVIEW OF THE SETTING

The term, science education center, is used here to designate an operational unit of a college or university consisting of identified personnel with responsibilities in the field of science education with programs of teaching, research, and service, and accompanied by facilities and resources to support the various programs and activities. In most institutions the science education center brings together faculty, facilities and resources to support the various programs and activities. In most institutions the science education center brings together faculty, facilities, and resources into a centralized location on the campus. Each institutional representative in the conference held a central responsibility for such a center.

It has become increasingly evident that an effectively designed and developed center can provide personnel, services, facilities, and resources for producing desired changes in the teaching of science. The survey of science education centers indicated there were relatively few centers in comparison with the number of colleges and universities in the country. Thirty-three science education centers were identified in the 1963-64 study. These centers varied extensively both with respect to the functions they were performing and to the resources available for maintaining their programs.

A commonly held conviction is that effectively designed and developed centers for science education can produce a significant impact on educational practice through research, instruction, and dissemination and demonstration activities. How to maximize the effectiveness of each center and the total effort was the purpose of the discussions and deliberations of the conference.

The conference participants were given three principal charges in their reactions to each of the papers presented:

1. What problems do we need to solve to strengthen and to improve research and learning in the field of science education?
2. How can your institution contribute most effectively to the effort?
3. What services, resources, and working relationships would enable your center to contribute more effectively in producing an impact on research productivity and educational practice.

SUMMARY OF THE CONFERENCE DISCUSSIONS

The initial discussions were concerned with an analysis of the adequacy of recent and current research efforts and some possible designs for improving the research. These were followed by consideration of the design of centers for science education and on issues and problems which should be subjected to research in such centers. The discussions of the closing days were concerned with the strategies of dynamics for changing educational practice, and developing a design for cooperative action which would provide a basis for improving research and changing educational practice.

The analysis of recent research indicated that neither the quantity nor the quality of the research was adequate. Six factors believed to be contributing to the problems were identified; they were the following:

1. Research personnel should be more adequately prepared for conducting the kinds of research needed.
2. Personnel should have adequate released time for research activities.
3. Research should be focused on critical issues and problems.
4. There is need to identify a terrain (or domain) of science education.
5. More adequate resources are needed by many centers.
6. Communication and cooperative action should be established among centers.

Discussions and recommendations relating to each of these factors are summarized.

Increasing the Competence of Researchers in Science Education

The needed preparation for competent researchers has been a concern of nearly every major discipline; science education is no exception as revealed in the conference. At least one organization has taken action in the form of a recommendation of the course experiences which an individual should have.[1]

Those institutions preparing researchers at the doctoral level in science education should have ongoing research to provide a research climate and practical research experience for the future investigator. Many institutions do not currently provide such experiences for their graduate students. It was recommended that all centers awarding the doctorate should strive to establish such programs which could involve their students.

Science education is a hybrid of the social sciences and the natural sciences. Thus, competence in psychology and sociology is needed in many types of educational research. Cooperative efforts by researchers in science education and related areas have characterized some research in an attempt to bring together various otherwise diverse understandings essential to research problems. The availability of competent persons from related fields for research in science education is a matter of increasing concern. It is evident that efforts should be made to provide graduates in science education with substantial study and research experience in such related areas as sociology and psychology.

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[1] Association for the Education of Teachers of Science, "Guidelines for the Doctorate in Science Education." (Mimeo). 1966

Consideration of current employment practices reveals that many recent doctoral graduates have become located in situations where only one other science educator is located or where the employed graduate is the only science educator. It should not be assumed that the recent graduate is adequately prepared with respect to the techniques of research methodology, nor that he has adequate breadth in its social and philosophical setting.

The development of post-doctoral fellowships could provide a possible solution for the inexperienced beginning instructor in science education and also for the more experienced professor who has not been involved in research. The post-doctoral program providing study of research methodology and participation in a strong ongoing research problem would provide more competent professors to direct research. Such experiences would provide insight into the function and operations of a center for science education.

Available Personnel with Adequate Time for Research in Science Education

An important contribution of any college or university should be the generation of new knowledge. The small amount of faculty time assigned by such institutions to research activities in science education is one of the major causes of inadequate research in the field. The evidence indicates that few centers have personnel with university released time for research activities. Those few who have such assignments have less than one-third of their time allocated for research purposes. Very few professors in smaller centers are given released time for research.

An adequate and competent faculty is needed to enable a center to function effectively. It is the judgment of the conference participants that at least one person at each center should be provided released time for research in science education to the extent of at least one-third to one-half of a normal load assignment.

The problem is further complicated by the inaccessibility of previous research reports; absence of an organization or agency to provide adequate assistance in making literature searches adds to present limitations. A Coordinating Center could provide such services. It would enable the researcher to function more effectively and to devote more time to research design, analysis, and communication of results.

Research Designed to Analyze and Explore the Basic Issues and Problems in Science Education

Summaries of group discussions indicate a consensus that the problems and issues as presented are among those of primary importance for research efforts. Early attention should be given to an analysis of existing research with respect to the various problems and issues; in such an analysis the relevance of the research to the problems and issues as well as its contribution to their solution and resolution are major objectives. This effort will require a planned and coordinated procedure for obtaining research materials, analyzing the documents, and presenting and evaluating the generalizations which are derived. When this task has been accomplished, priorities for needed philosophical and experimental research can be more clearly assessed than at the present time.

Among the major areas warranting early research study is the design and evaluation of teacher education programs. Few programs showing careful design with respect to learning theory could be identified; fewer still are subjected to continuous research to improve the product of the program. A second area of considerable concern is the current emphasis on teaching based upon the use of processes of science and a laboratory approach to learning science. There is, however, little research evidence to support the effectiveness of the process approach or any other approach in developing desired behavioral outcomes. More adequate research design for studying the teaching-learning problem should be developed. General techniques utilizing analyses of gross methods have not been adequate to the multi-faceted operation of teaching science and have yielded little data of high predictive value.

A third area of concern is the teaching of concepts in the school program. In the judgment of the conference participants, current research does not effectively resolve either the grade placement impasse nor the problems of methodology in concept development.

The urgency of resolving issues and problems in the field of curriculum at a time of widespread development of science courses is apparent. Most course development projects are not based on an analysis of available research; many also are not designed to be utilized in research of the particular concepts and teaching procedures being utilized. While not everyone agreed that research could precede the development of new curricular materials, there was total agreement that research should precede or parallel the development of materials and courses.

It was recognized that centers for science education should be actively involved in investigating problems such as those identified. There was consensus that each center should be involved in research related to at least one significant issue or problem and that the efforts should be coordinated.

Identifying the Domain of Science Education

Throughout the discussions considerable attention was focused on what concerns and activities were included within the field of science education. Because of the complex of interrelationships that are involved in science education, there is a need to clarify the domain of science education; this concern was presented in both the first and last of the conference papers. This development can be initiated through identification of the concepts and processes, and extended through a study of the interrelationships among these concepts and processes. From such understandings concepts of dynamic models of science education may emerge.

Past research has seldom been based on a theory or model which encompasses a broad consideration of the purposes of science education. Likewise, past research has not been additive to the extent that it would thereby clarify basic concepts and processes, nor does it facilitate the development and clarification of dynamic models of science education.

More Adequate Resources for Science Education Centers

The study of centers for science education revealed areas in which several institutions lack adequate resources for fulfilling the multiple functions of such centers. The lack of competent faculty has been previously established as a major limiting factor of many centers. Adequate faculty with complementary competencies should be provided for instruction, research, and dissemination and demonstration activities.

Facilities in many centers are not adequate in one or more major respects. Such shortcomings indicate the lack of adequate facilities for the teaching of science and the lack of adequate designs for such facilities. Very few centers have facilities on campus for conducting varied research and development activities. Centers which are reasonably well equipped for their instructional programs usually have very little space to utilize for research with groups of class size or even smaller.

Demonstrating innovations in teaching science requires a setting appropriate to the technique, procedure, and/or material being presented. Facilities for this function are nearly totally lacking in centers for science education. Effective planning could design and include a facility for both research and demonstration functions.

Lack of funds to purchase equipment and materials for research and development activities has also been a limiting factor in several centers. Portable television equipment, recording equipment, laboratory equipment, and library resources were identified as materials which were needed by several centers, but not available because of the lack of funds.

Communication and Cooperative Action Among Centers for Science Education

A major problem is that of the relation of individual centers in effective broad changes in educational practice. The individual center generally has neither the manpower nor the resources to provide the leadership and action needed to achieve desired goals; broad changes will result primarily from cooperative activity by several centers.

The survey of science education centers as well as common experience reveal that past research findings have not been disseminated; furthermore, even the current research and development efforts of various institutions are not clearly visible to other centers. Consensus indicated a desire to develop strong individual centers which could be assisted in extending the use of their resources through a Coordinating Center. Such an agency could assume selected functions which would enhance the operations of the local centers.

The conference participants identified various functions and services that should be provided by a Coordinating Center, either because they could be more effectively administered by such a Center or because local centers lack adequate resources for fulfilling the functions and services.

It is recommended that a Coordinating Center be created to acquire, abstract, store, and disseminate research and research related information pertinent to science education. Considerable time is currently being wasted in inefficient literature searches. Since no total analysis of research in science education is available, it is extremely difficult to know whether the investigator has obtained all pertinent research on a given topic.

A second function proposed for a Coordinating Center is the establishment of a communication network among centers for science education and related organizations and agencies. This service should involve utilization of existing communication media and development of further techniques to maintain cooperative relationships on curriculum instruction and research activity, to maintain an awareness of current research and developmental activities in the field, and to communicate interests and needs of various centers.

An important function, already identified, is the assumption of leadership in developing a synthesis of the domain of science education. This effort will require the cooperative efforts of many persons and agencies; it will be more effectively directed through a Coordinating Center which would utilize various individuals and local centers as needed.

THE CENTER FOR SCIENCE EDUCATION AS AN OPERATING UNIT

The discussions identified the desirability of individual centers for science education at selected colleges and universities with a single Coordinating Center to provide services and coordination to develop the maximum effectiveness and impact of the individual centers upon educational practice. While specific characteristics of centers for science education vary, the functions which they need to fulfill have been defined. Centers which currently are most effective in producing an impact on educational change generally have functions which may be grouped into four categories: (1) instruction, (2) research and development activities, (3) demonstration activities, and (4) dissemination activities. Each of these activity areas requires consideration in building an effective design for a center. The effective organization and operation of a center probably depends more upon the competency of its faculty and their understanding of the functions that it is attempting to perform than upon any uniform design for all centers for science education.

Qualifications of Faculty in a Center

Current efforts to organize an effective program for improving science education programs involve activities throughout the school and from the kindergarten through the junior college. Effective center design is one that contains faculty involved with science education across this entire spectrum.

A second important consideration in the choice of personnel for a center is that it should involve faculty from three fields: professional education, scientific fields, and related social sciences. A center that engages in instruction and research for all aspects of teaching and learning science should have at least one person in each of the following areas: (1) biological sciences, (2) physical sciences, and (3) earth sciences. Where the breadth and depth of preparation in both science education and science are adequate and the division of responsibilities warrant, the time of the individual faculty members may be shared.

The faculty of the center should have had teaching experience at the elementary school, secondary school, and college levels. Thus, a teacher of elementary teachers would be able to work with students from his own background of personal experience in solving similar problems.

Further, the faculty of the center should have developed a broad professional competence in research design and technical competence in its interpretation and demonstrated ability in curriculum development and in the supervision of science instruction. Their professional competence should include understandings of the history and philosophy of science and of their sociological implications. This competence should extend to include the historical and philosophical aspects of educational research and the insights and technical competence with such research.

The development of such a faculty for a center can bring together persons with the competence to develop an effective science education program of teaching, research, and service. Through cooperative activities they can focus on science education problems which extend across subject matter boundaries and grade levels.

Many research, development, demonstration and dissemination activities also require competencies which individual members of a science education faculty may not possess. In these instances working relationships should be established with faculty in the behavioral sciences, research design, and statistics.

Facilities and Resources for Instructional Programs

While an adequate faculty is the most important factor in building an effective center for science education, facilities and resources are also needed to develop an adequate program.

A broad teaching program will require two or more classroom-laboratories for courses in the teaching of science and for practicums in physical science, biological science and earth science. At least two classroom-laboratories are needed, one designed for courses in elementary school science and one designed for courses in secondary school science. The facilities should contain basic equipment and materials normally found in a good school. Supplementary facilities should include a preparation room, workshop area, darkroom facility and library or library area. These facilities enable the prospective or experienced teacher to have adequate experiences in studying the teaching-learning operation in a laboratory setting.

Student Populations and Other Resources for Research and Development

Special provisions for research activities should include working agreements with school districts and other organizational units that would provide desired student populations considering such factors as socio-economic backgrounds. Such agreements should provide also for the desired and necessary school facilities and teaching staffs.

Other facilities and resources are needed to develop effective research, development, and demonstration and dissemination programs. Facilities for the center should include an area for research activity. This should include an adequate library of reference materials, one or more calculators, and an abstract file and sorter. The center should have arrangements with other divisions of the institution so that computer facilities and portable television equipment are also available.

Development activities have some facility requirements similar to research needs, but also their own unique requirements. An adequate library and working relationships with schools are both similar facility needs. An example of a unique facility essential to developmental activities in curriculum is a special room in which curricular materials may be the basis for demonstration and experimentation. In such a facility, pilot studies involving selected student populations with particular curricular experiences, can be carried on as a means of innovating changes in practice.

Programs in schools are an essential vehicle to the center for science education as it developes research activities. As these are developed and utilized, their effectiveness in curricular design, and in such studies as those dealing with teacher preparation can be studied. Thus, the center functions in its own real laboratory in developing innovations and in their diffusion.

Cooperative Activities with Other Institutions and Organizations

The individual center should develop cooperative working relationships with other member centers in the promotion of research and in its appropriate development and utilization. In other instances the individual center may assist and cooperate with institutions attempting to develop their own science education programs and increase their contribution to the field through both instruction and research.

A science education center will also develop working relationships with the county and state departments of education and with professionsl and scientific societies. Such pacts will improve the quality of the professional work for all concerned; the quality of research will be improved as will curiculum development and science instruction in the schools.

SUMMARY

This section of the report is based upon an analysis of discussions and recommendations of the Green Meadows Conference. The analyses have indicated the establishment of strong local centers for science education in colleges and throughout the country is a major need for effecting desirable change in research activity and educational practice. As the parameters of the problem were identified and explored, it became evident that individual centers lack the manpower and resources to provide the combinations of services and functions which will develop the masimum effectiveness of each individual center.

SECTION VI

A DESIGN FOR ACTION

A major conclusion resulting from the year of study of the needs and potential of the field of science education became abundantly clear: the function of science in our total educational effort has not been realized. The variety of concepts of course work in science, the philosophical conflicts evident in the design of science curricula, and the lack of identifiable planned programs of instruction in science were among even more numerous elements of disarray in the field.

Such samples of inadequate achievement and unfulfilled functions are harbingers of serious problems and possible crises ahead in the field. An over-all appraisal is in order. Such a step should be based on an orderly identification of the elements that comprise science education, an assessment of the factors of strength and weakness and the derivation of procedures and programs through which the domain of science education can be more specifically known.

Some Developing Problems in Science Education

Major efforts to improve and extend science in our educational programs have, through their diversity and magnitude, created critical problems and issues that should now be faced realistically: Shall the central purpose of the science program be the development of process outcomes (critical thought) or the memorization and interrelation of bodies of scientific information? What is scientific literacy, and what is an acceptable level for our society? How can a defensible structure of scientific concepts be established? Through what means can such a structure (or structures) be developed into the scientific competence necessary for a citizen in our society?

The development of course content improvement programs (the so-called "new curricula") in science poses the urgent need of research as to their adequacy, their relation to other facets of school science programs, vocational plans, scientific literacy, and college entrance. The rapid growth of science in the elementary school curriculum introduces problems concerned with its relation to child growth and development, methodology of teaching, and adequate evaluation of outcomes. The extension of general education with our need for secure knowledge of the place of science therein raises basic problems for the total science curriculum. In the history of our country, and indeed, of Western society, the view of teaching is emerging from a teaching-is-telling concept to a considerably more responsible and sophisticated role. In such an educational setting the extension of science and its function in the programs of our schools and colleges obviously demands study and research. For such emerging programs, the present movements tending toward a standardization of requirements for the licensing of science teachers should be based upon fundamental research concerned with adequate and demonstrated qualifications for science teachers. Comparable research bearing on the competencies (or behaviors) of the elementary school teachers insofar as science is concerned and of college teachers will become even more urgent as educational programs are extended.

The influence of the economy on programs of science education is illustrative of an additional factor requiring not only scrutiny but research. The influence of printed materials on science education, essential as such media are in our instructional programs, is a complicating factor. Comparable problems are created by the great variety of other instructional aids -- models, projected materials, and science kits.

Other undeveloped facets include the psychological bases for curriculum and instruction, the sociological implications of science for school programs, science in the preparation of all teachers, and the adequate preparation of science teachers. A persistent deficiency of disturbing complexity and proportions is the state of the research productivity in science education.

Research, New Knowledge, and Development

While such factors as the preceding require new knowledge which can be gained only by more effective research, an essential ensuing activity is utilization of these findings in developmental activities. The new knowledge and findings resulting from the research of such problems as those stated and implied above should be disseminated and put into practice.

Certain factors have tended to limit this phase of the research cycle. The field of science education is a hybrid of the social sciences and the natural sciences; research in science education should reflect its inheritance. The definitive achievement of this characteristic is still in the future; moreover the development of the new knowledge resulting from such research is dependent upon the essential interdisciplinary communication at levels of the philosophical foundations of objectives, society's requirements relating to scientific literacy, and the fundamentals of interdisciplinary research.

A further limiting factor is that of obtaining action once the new knowledge has been gained and adequately disseminated. The need for the use of new knowledge may be clear and the evidence of its value unmistakable. Attitudes of the prospective user must be favorable; often a change of attitude is necessary. The desirability and feasibility of a proposed new development -- perhaps a modified sequence of study activities in science -- must be convincing.

Developing Plans for Action

That the field of science education is overdue for a general cooperative effort to find and develop ways and means of improving and refining the processes and products of professional work is generally acknowledged. Only through a coordinated approach can the end product, the learner, be most favorably affected. A comprehensive plan for well-designed action is the goal.

The Green Meadows Conference brought together the insight and talent of more than twenty-five persons with experience and responsibility in the field of science education. The analyses of the problems facing us and the synthesis of proposals for constructive action were directed toward the foregoing concerns. The rapid development of our educational programs, with larger dimensions and more distant horizons, now causes science education to reassess itself and plan ahead with new vision and vigor.

New Occasions Teach New Duties

The nature of the problems facing us, with their manifold ramifications, requires new systems of handling information in the field of science education. We stand in need of a central agency that will devote the full time of qualified persons working as a team of sufficient size that the scattered nature of our efforts and our results will be supplanted by a unified program that is more rapid, more comprehensive, more efficient, and more effective than that of our past labors.

It is evident that any proposed design for action should make provision for adequate communication among researchers in the field with respect to the many facets of research: objectives, designs, procedures, evaluation, results and conclusions, and the like. The dissemination and utilization of research and development information is a prerequisite to better educational programs, to the improvement of science teaching and to the optimal development of the field of science education.

Emerging from the field of science education is a strong conviction expressed by many of its leaders that the creation of a cooperative enterprise of those institutions now engaged in research in science education and in its application in the field (joined by others as they may develop such activities) is the most desirable step. To develop the full effect of such a body, a central agency to coordinate the facilitating services and resources would be developed.

> Clarification of Terminology. Such a cooperative plan or arrangement will be referred to at this point as a confederation of the educational institutions and other agencies involved; the central agency as the Coordinating Center for Research in Science Education.

The term, Center for Science Education, is intended to identify those faculty members in an institution devoting an appreciable amount of their time to instructional and research work in science education, its diffusion, development, and utilization in the schools and in other educational agencies; and to include the institutional facilities, resources, and activities associated with and essential to such persons. In contrast, the Coordinating Center for Research in Science Education would not engage in the usual activities characteristic of programs for the preparation of teachers in science at any level, although it is conceivable that, for research purposes, certain instructional functions might be developed.

Present and new Centers for Science Education would be located in colleges and universities committed to more intensive research and instructional activity. The Coordinating Center would probably not be identified as a singular function of any one institution although it would seem desirable that it be located in the vicinity of an institution having ready access to rich professional, scientific and research facilities, and to auxiliary personnel of various desired competencies.

The Coordinating Center for Research in Science Education

It is anticipated that those Centers that have thus far shown their dedication and productivity will choose to enter into the confederation with activities so designed as to strengthen the individual member Centers and increase their productivity. Such a confederation would serve also as a source of strength for the field as a whole in gaining resources and in effecting change in school practice as research findings provide insight. Membership and participation in such a Confederation would be extended beyond the institutions presently represented according to such criteria and procedures as would be adopted in an acceptable plan for action.

It is proposed that to serve the separate members of the confederation, a Coordinating Center for Research in Science Education be created. Suggested functions of such a center are delineated below.

To bring this Center into existence an Advisory Board of five members representing the initially cooperating institutions and agencies has been created.

Functions of the Advisory Board

1. To develop and interpret the appropriate functions of the Coordinating Center as suggested below

2. To develop the design of the Coordinating Center, including its optimum geographic location

3. To create a professional staff design for the operation of the Coordinating Center, assist in the selection of personnel, and supervise the operation of the Center

4. To develop policies relating to the financial operations of the Coordinating Center, assume advisory responsibility for the funding operations, and review the general administration of the fiscal operations

5. To develop policy relating to the field activity of the Coordinating Center

    a) As related to research and development in Science Education centers, both individually and in cooperative research and development

    b) As related to institutional programs; undergraduate and graduate instruction

    c) As related to research and development in non-institutional programs

Functions of the Coordinating Center for Research in Science Education

It is anticipated that the functions of the Coordinating Center would be of the following kinds:

1. To abstract, store, retrieve, and disseminate research reports and related literature in science education

2. To assist in the planning and coordination of cooperative programs among the member Centers for Science Education: research, instruction, curriculum development, and others

3. To provide assistance and service to member Centers through panels and committees for advisory and consulting functions

4. To serve an instructional function for the field through internships in the Coordinating Center, with the potential avenues being informal study and research experience in the Center and/or formal study in an associated institution

5. To cooperate with those professional and scientific organizations concerned with research and development in science education

6. To extend the work and influence of the Coordinating Center by encouraging and working with new Centers

7. To carry forward particular research studies through the Center staff or in cooperation with other research personnel

8. To develop and maintain general and specific communication with not only member Centers of the Confederation, but also with various educational agencies (e.g., state departments of education and individual school systems) and various governmental agencies (e.g., the U.S. Office of Education and the National Science Foundation)

9. To provide a general information service in science education for individuals and agencies in the field having need of such assistance

10. To engage in activities directed toward the refinement of research design, the extension of its meaning, and the dissemination and application of research findings

The organizational relationships of such functions and personnel are presented in Figure 1 on page 127.

Observations of the Functions of the Coordinating Center

The first of these functions is identified in Figure 1, ORGANIZATION CHART, in locations 1, 2, and 3.

Educational Research Information Center

The functions of abstracting, storing, and retrieving research information involves more specifically such operations as the following:

To receive and file reports of educational research and related literature.

To digest reports of educational research in science education; relate such to on-going abstracts, digests, briefs, and reports.

To develop pattern and program for the production and organization of abstracts of research reports.

To develop a realistic, but evolving, system of information retrieval.

To provide for and participate in information exchange between and among participating members and agencies.

To identify productive sources of research results in science education.

Provision and Development of Leadership

The leadership functions of the Coordinating Center are suggested

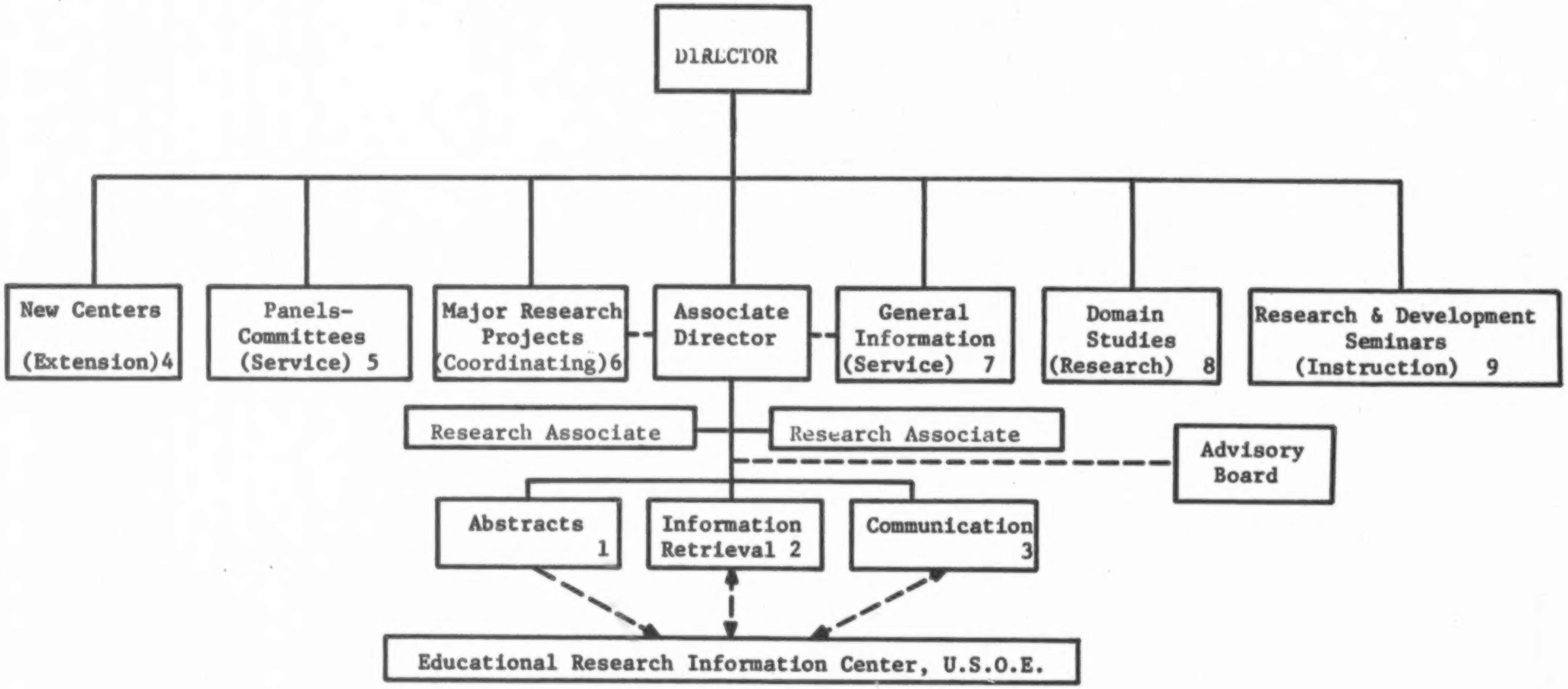
DIRECTOR
New Centers (Extension)4
Panels-Committees (Service) 5
Major Research Projects (Coordinating)6
Associate Director
General Information (Service) 7
Domain Studies (Research) 8
Research & Development Seminars (Instruction) 9
Research Associate
Research Associate
Advisory Board
Abstracts 1
Information Retrieval 2
Communication 3
Educational Research Information Center, U.S.O.E.

Figure 1 - ORGANIZATION CHART: Coordinating Center for Research in Science Education

on the ORGANIZATION CHART in locations 4, 5, 6, 7, and 9. More specifically such approaches as the following would be involved:

The creation of additional Centers for Science Education provides the opportunity to give assistance to institutions desirous of improving their educational programs and in other ways be of service to the field of science education. Ready access to the experience of other institutions and to the investigations setting forth the programs and personnel is a facilitating factor in such a relationship. Additional institutions will be determined on the basis of factors to be established, subject to the approval of the Advisory Board. Such factors would include evidence of current qualified personnel in science education, devotion of a significant amount of time by such personnel to research, research libraries and other resources for facilitating research and the dissemination of research products.

Panels and committees can assist individual school systems in the planning of studies relating to the appropriateness of curricular materials, evaluation instruments, design for research studies, and others. Likewise, such panels can help design programs for teachers and administrators and assist the Coordinating Center by advising on needed field projects, their design and execution. They may serve as long-range consultants on major research projects in the field.

Such panels could take the form of a cooperative exchange program involving graduate students, local teachers, and science education faculty on a fellowship basis. This activity could be assisted by the Coordinating Center which would aid in providing an adequately balanced program and obtaining persons desiring the various experiences.

In other ways the leadership function may be identified through the staff of the Coordinating Center. Leadership activities in science education research can take such forms as arranging conferences and programs of persons concerned with and competent in this field, and publishing such direct and related material as will serve those responsible for research in the field. The research and development seminars can serve as a central focus for contributing to the research talent in the field and increase the quality of various instructional materials developed under such auspices.

Cooperation with Other Educational Agencies

A major function of the Coordinating Center is the development of mutually useful activities and relationships with the various public educational offices. Those of federal and state operation would be served by the Coordinating Center which, in turn, as an arm of the confederation would benefit by the official liaison and through such service to the field of science education. The cooperating roles of the various divisions of the U. S. Office of Education, the National Science Foundation and other government agencies are examples at the federal level. State Departments of Education and other comparable state agencies are potential resources and avenues extending both the competence and the influence of the Coordinating Center for Research in Science Education.

The various professional and scientific societies are sources of inspiration and strength to the field. In turn such organizations can multiply their leadership and educational effectiveness through the Coordinating Center. The National Association for Research in Science Teaching, the National Science Teachers Association and other scientific and professional societies have much to contribute and much to gain in the effort to improve research and development in science education.

Separate Science Centers, such as those of municipal, institutional, or museum nature, are educational agencies having much to gain through liaison with the Coordinating Center. Such centers and other private and commercial enterprises may plan with the Confederation to enter into the exchange of educational information with mutual benefits accruing.

CONCLUSION

The design and creation of a body, a Confederation, with a Coordinating Center as a focus, has the potential of bringing present and future resources in science education directly to bear on the needs and problems of the field. A year of study involving investigation, conference and deliberation has provided the insight, perspective, and general design of efforts and programs to relieve and rectify many well recognized weaknesses and shortcomings.

Science education is in need of more comprehensive and more definitive research, and of more adequate means of translating the results of that research into valid programs of action. Such programs of action in the classroom result in improved teacher competence or behavior; research findings in science curriculum combined with increased teacher competence improve the quality of the learning experience: the learner in the classroom is the direct beneficiary.

The conclusion is inescapable because it is direct, and because it places a certain responsibility upon those institutions having the teacher education function to move together in meeting this challenge to science education.

* *

ADDENDUM

Approximately one month before the closing date of the project reported herein, a proposal to create an ERIC Information Center on Science Education was approved. This action has enabled the staff to initiate those essential actions in the research effort -- the abstracting, storing, and retrieving of research information in science education. The ERIC Center was developed with the advice and assistance of the Advisory Board anticipated and approved at the Conference and identified in this report. Future planning by this body and the staff is continuing.

APPENDIX

PROJECT PERSONNEL

PROJECT STAFF

Dr. John S. Richardson
Director

Dr. Robert W. Howe
Co-Director

INITIAL ADVISORY COMMITTEE

Dr. J. Darrell Barnard

Dr. Addison E. Lee

Dr. Stanley E. Williamson

ENLARGED ADVISORY COMMITTEE

Dr. J. Darrell Barnard

Dr. Addison E. Lee

Dr. Milton O. Pella

Dr. H. Craig Sipe

Dr. Stanley E. Williamson

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National Science Teachers
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Teachers College
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University of Iowa

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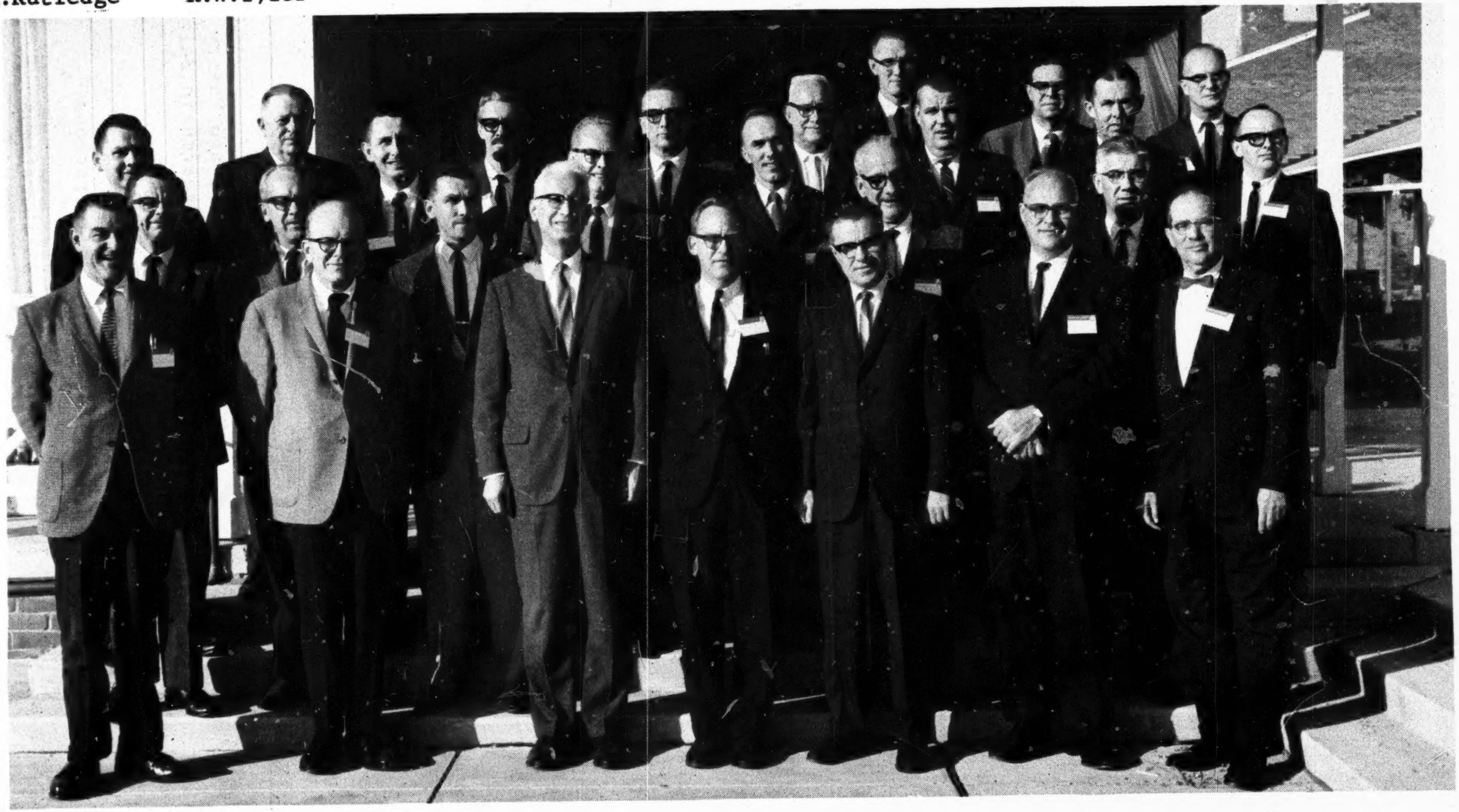
J.D.Lockard R.H.Carleton V.N.Rockcastle E.Burkman D.H.Dillman

H.S.Fowler T.R.Porter L.W.Trowbridge J.D.Barnard M.O.Pella

J.A.Rutledge R.W.Tyler J.S.Richardson K.S.Ricker C.H.Boeck H.C.Sipe J.G.Read



SCIENCE EDUCATION CENTERS FOR RESEARCH AND DEVELOPMENT

THE OHIO STATE UNIVERSITY
NOVEMBER 1 - 5, 1965

PROGRAM

Monday, November 1

9:00 - 9:30 a.m.	Registration
9:30 - 10:00 a.m.	Introductions John S. Richardson Director, Conference Program Professor of Science Education The Ohio State University Greetings Donald P. Cottrell Dean, College of Education The Ohio State University "Rationale for the Conference" J. Darrell Barnard Chairman, Department of Science Education New York University
10:00 - 11:15 a.m.	"Analysis of Strengths and Weaknesses in Current Research in Science Education" Ralph W. Tyler Director, Center for Advanced Study of the Behavioral Sciences Stanford, California
11:15 - 11:45 a.m.	Details on Conference Administrative Concerns
1:15 - 2:30 p.m.	Small Group Deliberations
3:00 - 4:00 p.m.	Small Group Deliberations

Tuesday, November 2, 1965

9:00 - 10:15 a.m.	"Resources, Models, and Theory in the Improvement of Research in Science Education" Ralph W. Tyler
10:45 - 12:00 noon	Small Group Deliberations
1:30 - 2:30 p.m.	Small Group Deliberations
3:00 - 4:00 p.m.	Total Group Discussion - Summary

Wednesday, November 3, 1965

9:00 - 9:45 a.m.	"Research of Issues and Problems through the Resources of Science Education Centers" Stanley E. Williamson Chairman, Department of Science Education Oregon State University
9:45 - 10:30 a.m.	"The Center for Science Education in Changing Educational Practice" Addison E. Lee Director, Science Education Center University of Texas
11:00 - 12:00 noon	Small Group Deliberations
1:30 - 2:30 p.m.	Small Group Deliberations
3:00 - 4:00 p.m.	Total Group Discussion - Summary

Thursday, November 4, 1965

9:00 - 10:00 a.m.	"Centers for Science Education: Functions and Designs" Robert W. Howe Co-Director, Conference Program Associate Professor, Science Education The Ohio State University
10:30 - 11:30 a.m.	"Strategies and Dynamics in Changing Educational Practice" David L. Clark Professor of Education The Ohio State University
1:15 - 2:30 p.m.	Small Group Deliberations
4:00 - 5:00 p.m.	Total Group Discussions - Summary

Friday, November 5, 1965

9:00 - 10:00 a.m.	"A Design for Action: Guidelines and Proposals" John S. Richardson
10:30 - 12:00 noon	Small Group Deliberations
1:15 - 2:30 p.m.	Total Group Discussion
2:30 - 3:00 p.m.	Closing of Conference